Running Tezos on a Raspberry Pi

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1 Abstract

Tezos is an environmentally friendly Proof of Stake blockchain. It does not need lots of computing power to process new transactions onto the blockchain. It can run on domestic computing equipment.

There is at least one baker running Tezos on a small computing platform (Tezberry Pie). Others are experimenting with Raspberry and Orange Pi boards.

I wanted to see if it was possible to effectively run the Tezos software on a small inexpensive machine. In this article, I examine running the Tezos software (Octez) on a Raspberry Pi computer. We use a Raspberry Pi 4 for most of the testing.

The Tezos Foundation supported this work by providing a grant for the stake to run a baker on mainnet and covered equipment costs.

Figure 1: The author with a Raspberry Pi

2 Introduction and Findings

2.1 Scope

Recently, I asked around to see if anyone was using a Raspberry Pi for Tezos. I got mixed reactions. One of the problems reported was the time it takes to build the software. There have been reports that 8GB

is not enough to hold the memory pool on mainnet. Another report was some perceived performance issues keeping up with the network. I decided to put it to the test myself.

I run the Tezos Foundation bakers. We use large instances on AWS to run the software. We use an industry standard hardware security module to protect the baking keys. They have very good network connectivity. These bakers rarely miss an endorsement or a block. If they do, it is usually caused by an event on the network.

Similarly I run a personal baker on a machine at home. It is domestic PC hardware with 16GB of memory and 1TB of fast SSD disc. This machine bakers and rarely misses an endorsement. It is not overloaded and I can do other things with it whilst it is baking.

There are no recommendations made for running a node. But from experience I would use at least 8GB of RAM on a test network and 16GB of RAM on mainnet. 8GB is currently the largest amount of memory the Raspberry Pi platform supports.

The storage needs to be fast so that the node can write the blockchain to the disc in time. I would recommend at least an SSD drive. I have run PC hardware with traditional hard drives and have not been able to keep up with the blockchain. The Raspberry Pi boots from an SD-Card but this is not suitable for heavy storage operations. You must use an external drive for the blockchain data.

Figure 2: The haul

To write this paper, I purchased two of the following:

- Raspberry Pi 4 Model B with 8GB RAM - £125
- Official Raspberry Pi case - £8

- 128GB SD card - £13
- Fast 2TB SSD USB external drive - £96
- Dedicated power supply - £11

The equipment cost a grand total of £253. This is a lot to pay for such a machine but there is currently a shortage of components which pushes the price up. As I conclude this report, the Raspberry Pi 4 has dropped in price to £75.

Additionally I bought a Ledger S+ (£70) to hold the baking keys. One of the Raspberry Pis used the ledger. We have two machines as pictured in fig. 3 below: Ronnie and Reggie.

Hence with the Raspberry Pi platform:

- Running a node £253
- With ledger £323

Both machines identify as “Raspberry Pi 4 Model B Rev 1.5” with 8GB of RAM. The 4 CPUs are Cortex-A72 model 3s.

Figure 3: Ronnie and Reggie

Below, we document our experiments on Raspberry Pi. First we:

1. Set up a Raspberry Pi 4 from scratch, ready to run Octez
2. Build Octez on the machine

Then we test the platform to see how well it performs. We:

3. Run an archive node
4. Reconstruct an archive node from a full node
5. Operate as an independent client machine
6. Run a baker on mainnet with a Ledger for key management
7. Run a baker with a Remote Signer for key management
8. Providing a VDF service
9. Run a Smart Rollup operator on Ghostnet for the EVM rollup

When we started this exercise, the current Octez release was 17.1. The protocol was Nairobi. As we conclude, the current Octez release is 18.1. We have used 17.1, 17.2, 17.3 and 18.1 in the testing. The differences between the 17 releases would not affect the testing outcomes.

We did tests on the production mainnet or the development ghostnet as appropriate. The Raspberry Pi was setup on the wireless network, then the VDF tests performed. After this we put the Raspberry Pi on a wired network. The network was a FTTH network with up to 500Mb/s download speeds.

We have used the English Chemistry lesson approach: *Aim*, *Method*, *Results* and *Conclusion*. Sometimes we have reported findings in the *Method* as we go.

2.2 Findings and Conclusions

Here is the summary of our findings:

The good news is that the Raspberry Pi 4 was able to do most things that a consumer Tezos user would want to do. The bad news is that as a baker it appeared to miss more endorsements than a regular domestic PC. Additionally, it is not good for memory intensive operations. It cannot run a VDF service.

It can built the Octez software from the source code. It takes more time than other domestic PC equipment. As a result, most users will want to use pre-packaged versions of Octez. Tezos Foundation provide these [8] and Nomadic Labs will in 2024. The packages will be available on the day of each release.

The two simplest packages are the client and the signer. Both of these work very well on the Raspberry Pi. The signer performed well when serving a key for a baker. We tested the client with a remote node. Together with an encrypted file system, one can use the Raspberry Pi as a safe key store.

Raspberry Pi Experiments

Test	Started	Completed	Status	Notes
Building Octez	30/06/2023	30/06/2023		Takes approximately 2 hours
Archive node (mainnet)	30/06/2023	06/07/2023		Took 10 hours to download. Archive directory at 1.1TB. Ran fine.
Archive node reconstruction	06/07/2023	26/07/2023		Expected to take weeks... (17th July at cycle 416 of 623, 26th July at 419). I stopped at 419. In principle it will work but it will take an unfeasibly long time.
Octez Client	02/07/2023	02/07/2023		As expected all works. Also in baking section we use the client with a ledger and in the signer section with the signer (this has been previously verified).
Baking on Mainnet with a Ledger	28/07/2023	20/09/2023		Baking but with endorsement misses. Every cycle has at least one endorsement miss. This could be the ledger of course.
Baking on Mainnet with a Consensus key on disc	17/10/2023	11/11/2023		Feels more performant than the ledger setup, but perhaps more missed endorsements than one might expect
Baking on Ghostnet with a key on disc	11/11/2023	21/11/2023		Similar outcome to the consensus key testing
Baking on ghostnet with a Remote Signer on a separate Pi	16/12/2023	28/12/2023		Remote Signer is capable of signing transactions in a hard loop. Also capable of signing within the block timeframe.
Running VDF (mainnet)	30/06/2023	01/07/2023		Cannot work within 8GB of RAM. Wedged the Raspberry Pi. Interestingly rolling node synced over WIreless.
Smart Rollup Observer node (Ghostnet)	26/11/2023	07/12/2023		The node was able to join the Etherlink MVP smart rollup and observe the rollup, storing it to disc. It ran a Rolling node at the same time. It was able to participate, but memory usage was high. It's difficult to say if the Pi would cope in real life.

Figure 4: The results

The Raspberry Pi is capable of supporting an archive node on mainnet. This means it is capable of supporting all history modes on all current test networks. On a few occasions the machine would lose synchronisation but it would catch up very soon. This is not unexpected behaviour.

The Pi is also capable of running the baking processes on the same machine as a node. We were able to bake using a key on a ledger, a consensus key and a key directly on the file system. But we did see slightly more missed endorsements than expected. The causes were not clear. Hence we have marked the results as “Green/Amber”.

As an experiment, we joined the Etherlink MVP test Smart Rollup on ghostnet. The Pi was capable of running an operator on the same machine as the node. The recommended memory size for an operator is 32GB. So we suspect that the Pi would not be suitable for production use. We would like to revisit this in the future.

We knew before that the VDF service would fail. We have seen it fail on 8GB virtual machines before. The service needs 16GB of memory to run well, but we ran the test to see what would happen.

The Raspberry Pi equipment we used including the ledger costs between £250 and £350. The variance depends on the state of the world and the availability of chips. For comparison, my baking PC cost £500 around 2 years ago and included two drives.

We conclude that the Raspberry Pi gives us an affordable and capable platform to run Tezos. One has to accept the occasional inconvenience such as a few missed endorsements. But if you want something better, you should consider investing a bit more money.

We tested almost everything on a Raspberry Pi 4. We have investigated the Raspberry Pi 5 and at first glance, it is twice as fast. An increase in Octez performance was not particularly observable. Octez is typically I/O bound rather than compute intense.

2.3 Afterthought: The Raspberry Pi 5 and the Orange Pi

I had hoped to get this report finished some time ago, but other things took over. As we wrote this, the Raspberry Pi 5 was released. It is twice as fast as the Pi 4, but is still limited by the 8GB memory size. The Pi 5 case comes with a fan and heat-sink. It runs warmer than the Pi 4, but it is still an inexpensive computing platform.

We used the Pi 5 in one test scenario. We tested the baker on it using a remote signer on a Pi 4. There was only a slight difference in performance on Tezos between the two.

The Raspberry Pi 5 builds Octez much faster than the 4. Please see my blog article for more information.

The Orange Pi is a different Arm-based small board computer. It is available with 16GB of RAM. Although

I purchased one earlier in 2023, I have not had time to test it. It runs Armbian Linux. Emma Turner at Trilitech is using Orange Pis for testing and they perform well enough to run Octez.

3 Setting up the Raspberry Pi

To get started we need to install the SD card with the Raspberry Pi operating system. The easiest way to do this is to use the Raspberry Pi imaging tool, available from the Raspberry Pi website. Download the imager for your main computer. It is available for Windows, Ubuntu Linux and macOS. The computer will need an SD card slot or you will need to use a dongle with one.

Be careful. Imaging the wrong drive may result in loss of data. The Raspberry Pi installation routine is also subject to change.

We need to install the 64-bit version to support Octez. We will also setup the machine make it easier to login to the machine without a keyboard and monitor.

Insert the SD card into your main computer and run the imaging application.

Figure 5: Imaging Application

Choose *Raspberry Pi Other* and then choose Raspberry Pi OS Lite (64-bit).

Then click the storage button to choose the SD card. It's important that you pick the correct device here to avoid data loss. Here I have an external drive and the SD card. I will pick *Multiple Card Reader Media - 127.8GB*.

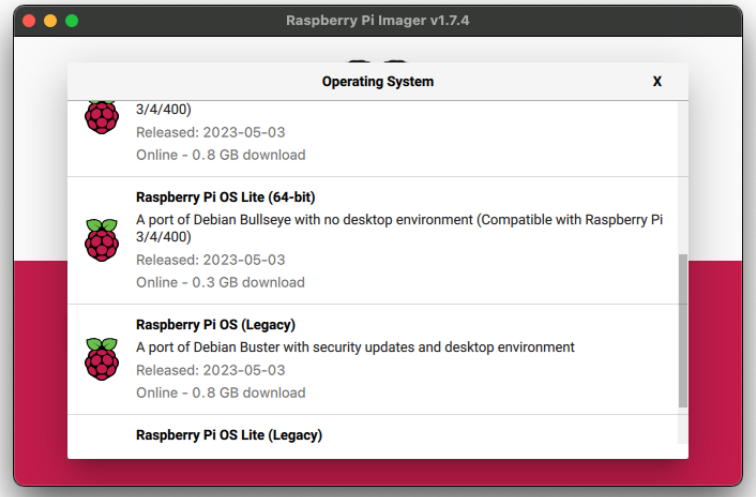

Figure 6: Picking the OS

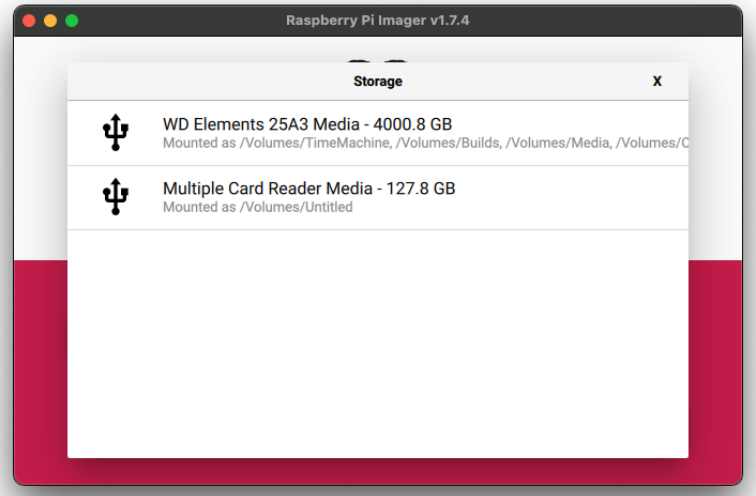

Figure 7: Picking the drive

Before we write anything to the card, click the settings cog. We will set preferences so that the machine is ready on its first boot.

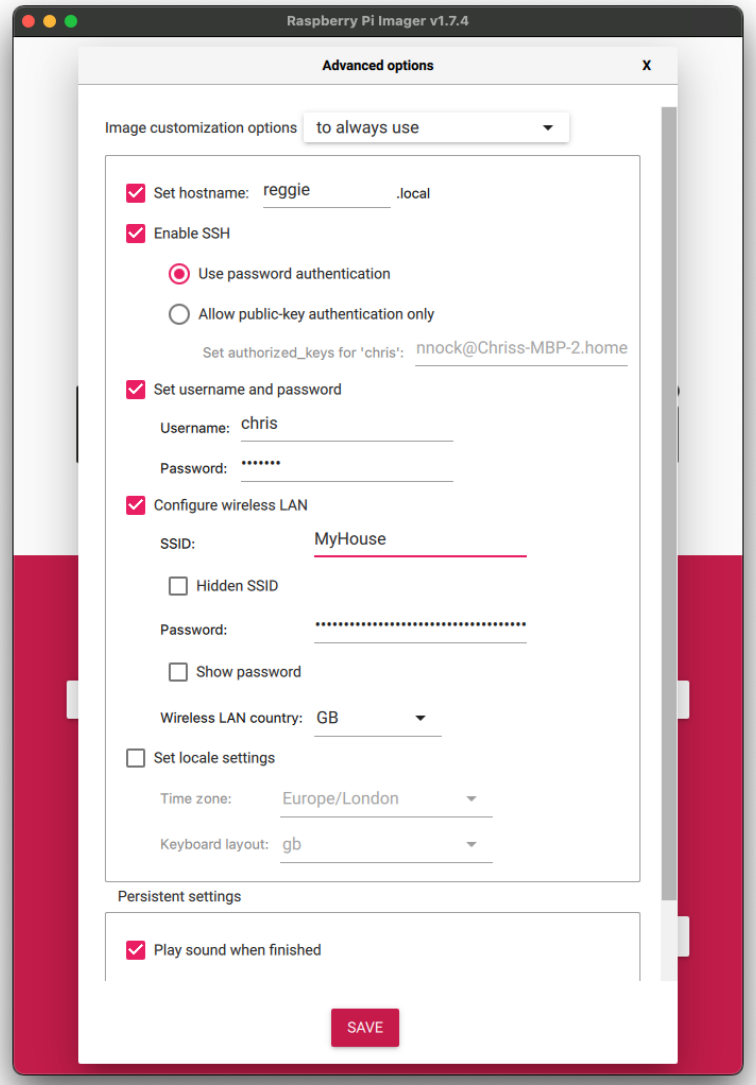

Figure 8: Settings

Change the details to suit your network and preferences. Here we:

1. set the host-name to *reggie*,
2. enable the secure shell service (SSH).

On the first boot the machine will join the network and allow logins. We do not intend to use the WiFi network long-term but it is useful to set it now.

Click Save and then click Write. The imager writes the Operating System onto the SD card along with the initial settings. The imager will verify the SD card afterwards. The imager will usually tell you that you can remove the SD card at the end. But you might need to eject it first.

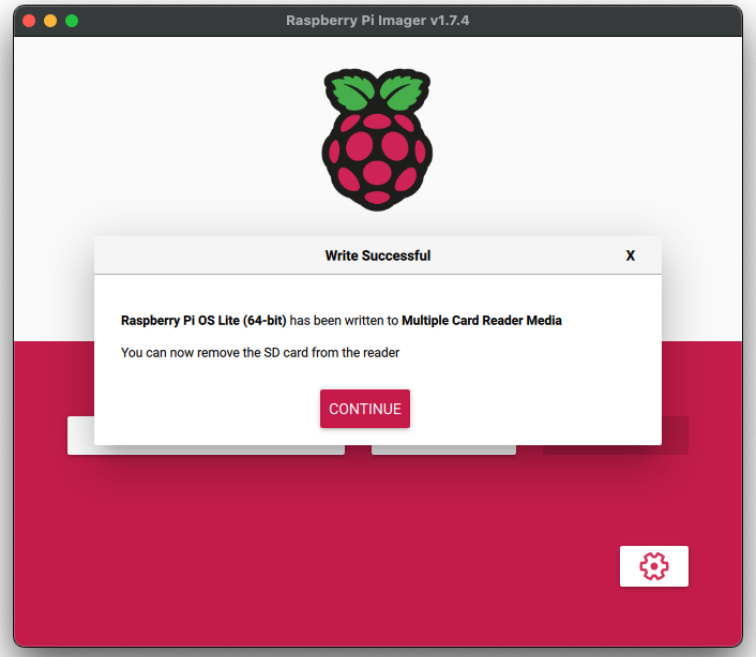

Figure 9: All finished

Remove the SD card and place it into your Raspberry Pi. If you haven't done this before, it can be a little fiddly particularly with a case.

Plug the SSD drive into one of the fast blue ports on the Pi and then power the Pi on.

On my network, my router automatically detects the names of the systems on it. So I was able to find *reggie* straightaway. On your network, you may need to check your router's network table to find the device. I logged into the new Raspberry Pi using the username and password I set in the imaging process.

I am using a Mac and the iTerm2 application. The process will be similar on a Linux machine. On Windows, you can use Putty.

We are almost ready to install Octez and try our first project, but we need to setup the SSD drive for use. This can be a little daunting if you have not done it before. We will need do most of the operations as the *root* user to begin with. The account created in the installation process has "sudo" access and we can get root access with it.

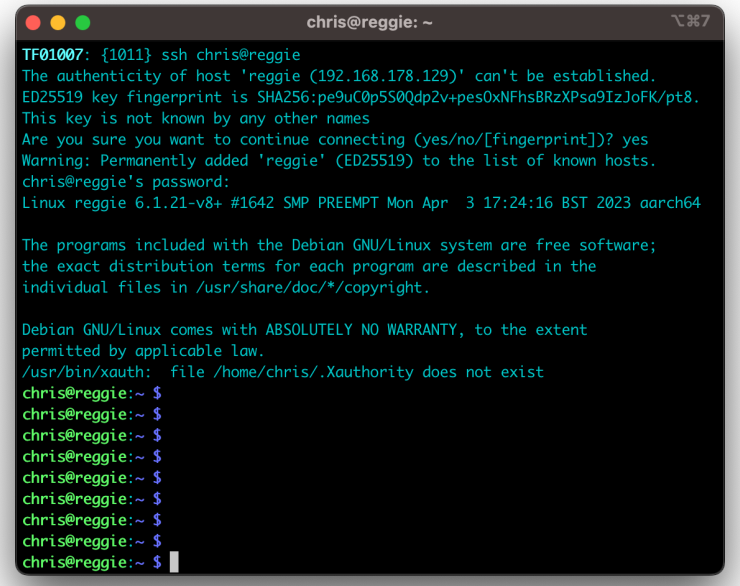

Figure 10: Logging into the Pi

```
sudo -s
```

We need to find our external drive and to do this we use `lsblk`. Below is the list of drives on our Pi. The *mmcblk0* device is the SD card with the */boot* partition and the main */* partition. The *sda* device is the external SSD drive and has two partitions on it. This might be a different device on your setup.

```
root@reggie:/home/chris# lsblk
NAME        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda           8:0    0   1.8T  0 disk
- sda1        8:1    0   128M  0 part
- sda2        8:2    0   1.8T  0 part
mmcblk0     179:0    0 119.1G  0 disk
- mmcblk0p1 179:1    0   256M  0 part /boot
- mmcblk0p2 179:2    0 118.8G  0 part /
```

We write a new partition table to *sda* using `fdisk`:

```
root@reggie:/home/chris# fdisk /dev/sda

Welcome to fdisk (util-linux 2.36.1).
Changes will remain in memory only, until you decide to write them.
Be careful before using the write command.
```

```
Command (m for help): g
Created a new GPT disklabel (GUID: 152865B3-E101-1A4D-B793-6C88A375E871).

Command (m for help): n
Partition number (1-128, default 1): 1
First sector (2048-3907029134, default 2048): 2048
Last sector, +/-sectors or +/-size{K,M,G,T,P} (2048-3907029134, default
   3907029134):

Created a new partition 1 of type 'Linux filesystem' and of size 1.8 TiB.

Command (m for help): w
The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.
```

The `lsblk` command shows we have one partition on *sda* now:

```
root@reggie:/home/chris# lsblk
NAME        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda           8:0    0   1.8T  0 disk
- sda1        8:1    0   1.8T  0 part
mmcblk0     179:0    0 119.1G  0 disk
- mmcblk0p1 179:1    0   256M  0 part /boot
- mmcblk0p2 179:2    0 118.8G  0 part /
```

We create a file system on the partition. We will use the standard file system on Linux, *ext4*:

```
root@reggie:/home/chris# mkfs.ext4 /dev/sda1
mke2fs 1.46.2 (28-Feb-2021)
Creating filesystem with 488378385 4k blocks and 122101760 inodes
Filesystem UUID: 3ccfa71f-2c75-46c4-bb79-f1782950e962
Superblock backups stored on blocks:
    32768, 98304, 163840, 229376, 294912, 819200, 884736, 1605632,
       2654208,
    4096000, 7962624, 11239424, 20480000, 23887872, 71663616, 78675968,
    102400000, 214990848

Allocating group tables: done
Writing inode tables: done
Creating journal (262144 blocks): done
Writing superblocks and filesystem accounting information: done
```

The modern view on referring to devices is via their block ID. Obtain the partition's block ID as follows:

```
root@reggie:/home/chris# blkid /dev/sda1
/dev/sda1: UUID="3ccfa71f-2c75-46c4-bb79-f1782950e962" BLOCK_SIZE="4096"
   TYPE="ext4" PARTUUID="563cae6c-abcd-1645-a202-97a79d636f1f"
```

Now we can make a mount point */var/tezos* and change the file system table so that */var/tezos* is

mounted at boot time. In our example, we place the following in */etc/fstab* using the *PARTUUID* obtained above.

```
PARTUUID="563cae6c-abcd-1645-a202-97a79d636f1f" /var/tezos  ext4    rw  0
     0
```

Now create the mount point and mount the drive:

```
root@reggie:/home/chris# mkdir -p /var/tezos
root@reggie:/home/chris# mount /var/tezos
root@reggie:/home/chris# df -h /var/tezos
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda1       1.8T   28K  1.7T   1% /var/tezos
```

We have successfully added the drive to the Raspberry Pi. Now we upgrade the operating system and give the system a reboot.

```
apt update -y
apt upgrade -y
shutdown -r now
```

When the system comes up, log in again and check that the drive is correctly mounted at */var/tezos*.

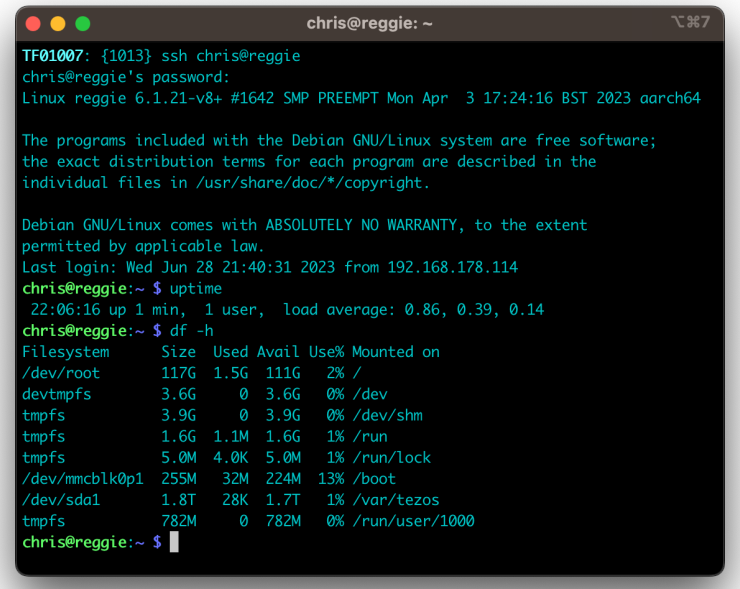

Figure 11: Ready to go

4 Building Octez

4.1 Aim

Now that we have a working Raspberry Pi with a working hard disc, we are going to build the Octez software from scratch.

4.2 Method

We follow the guidelines for setting up a development environment from the Octez documentation [1].

Install the prerequisite packages:

```
sudo apt-get install -y rsync git m4 build-essential patch unzip wget opam
    jq bc
```

Use the Rustup bootstrap script to install Rust.

```
wget https://sh.rustup.rs/rustup-init.sh
chmod +x rustup-init.sh
./rustup-init.sh --profile minimal --default-toolchain 1.64.0 -y
```

On a relatively fast connection, the above installations take less than 5 minutes.

Now add the Rust compiler to your path:

```
source "$HOME/.cargo/env"
```

It is prudent to add this line into your *.bash_profile* file as well, so that it is sourced with each new shell. Check that your PATH contains *.cargo/bin* in your home directory:

```
chris@reggie:~$ echo $PATH
/home/chris/.cargo/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/
   sbin:/bin:/usr/local/games:/usr/games
```

Now checkout the Octez source code and checkout the latest release. At the time of writing this is v17.1. See Octez Gitlab site. On a fast connection, this takes under 2 minutes.

```
git clone https://gitlab.com/tezos/tezos.git
cd tezos
git checkout latest-release
```

Most of Octez is written in OCaml and we use the OCaml Package Manager (opam) to install dependencies. First we setup opam (about 1 minute):

```
opam init --bare
```

At the end of the setup, opam will ask you if you want to modify your shell's startup configuration to run a hook script to keep your shell's environment in sync with the opam packages. You do not have to do this unless you want to explore opam and Octez further.

Then we build the dependencies needed for Octez. On *reggie*, this stage took 77 minutes. During the build, it's possible that more operating system dependencies will be installed.

```
make build-deps
```

Now we can build the Octez binaries themselves, which took 54 minutes on *reggie*. The `eval` command updates the shell environment from opam.

```
eval `opam env`
make
```

4.3 Results

I built the binaries in approximately 54 minutes. This included installing the prerequisites and building the software itself.

If at all possible, one should avoid heavy activity on the SD card. I repeated the experiment but this time building on the SSD drive. To my surprise this didn't make much of an impact. The cause could be that my home directory (including the *.opam* directory) were on the SD card.

I ran a further test with the home directory on the SSD drive. During the course of this build, the Raspberry Pi crashed and I could not login. It's not clear why this happened.

```
mac: {1016} ssh chris@reggie
chris@reggie's password:
client_loop: send disconnect: Broken pipe
```

But I was able to reset and complete the build. Here are the differences in timings for the two key stages:

	build-deps	make
SD card	77m7s	54m28s
SDD disc	82m1s	57m44s
Home on SDD	77m32	52m38

	build-deps	make
Macmini M1 2020	8m	5m10
Linux PC	7m8	4m36

4.4 Conclusion

It's possible to build the Octez software on the Raspberry Pi. The process takes approximately 2 hours and 20 minutes. This is a long time compared to other platforms. On a PC with Ubuntu Linux 22.04 (AMD Ryzen 5, 12 cores, 16GB) it takes approximately 15-20 minutes. I get similar results on a Macmini (2020 M1, 16GB, 8 cores).

Thus for Raspberry Pi users, it is more convenient to use pre-built binary packages. I have prepared packages on *ronnie*. One advantage of using them is that they contain startup scripts where needed. The packages are available at pkgbeta site. Throughout the rest of the article we will use these packages.

Alternative packages are available from other sources.

One thing to note is that we will run the software under a dedicated user called *tezos*. The package manager adds the user automatically. We need to do one piece of housekeeping to make sure that the *tezos* user can access the SSD drive.

```
sudo chown -R tezos:tezos /var/tezos
```

We also adjust the configuration so that logs also get stored on the external drive. We do this by setting `logdir=/var/tezos/log` in */etc/octez/node.conf*.

5 Running Archive Nodes

5.1 Aim

To see if the Raspberry Pi platform will function as an archive node on mainnet.

We will set up and monitor the performance of archive nodes setup in two ways:

- using a recent dump of the blockchain from https://xtz-shots.io[1]

[1] Since this was written, xtz-shots has discontinued archive downloads. They are now available at https://snapshots.tzinit.org/

- by recovering a full node from a snapshot and rebuilding an archive node

The Raspberry Pi was on the wired network for this test.

5.2 Method

In each case, we setup the node by installing the packages and configuring Octez first. Xtz-shots provides the archive compressed with lz4. As root:

```
sudo apt install lz4
sudo dpkg -i octez-rpi-unoff-client_17.1-1_arm64.deb \
    octez-rpi-unoff-node_17.1-1_arm64.deb
```

5.2.1 From a tar archive

Obtain an archive from xtz-shots.io and decompress it. We will do this in one line of shell commands to avoid downloading it directly. (This step took 10h9m10s).

```
sudo su - tezos
rm -rf /var/tezos/node
mkdir -p /var/tezos
cd /var/tezos
curl -L "https://mainnet.xtz-shots.io/archive-tarball" \
        | lz4 -d \
        | tar -x -C "/var/tezos"
```

We will use a slightly different directory structure to xtz-shots, so we modify:

```
cd /var/tezos/node/
rm chain.snapshot.sha256sum
mv data/* .
rmdir data
```

Now setup the node configuration for mainnet and archive mode.

```
sudo su - tezos
octez-node config init --data-dir /var/tezos/node \
            --network=mainnet \
            --history-mode=archive \
            --net-addr="[::]:9732" \
            --rpc-addr=127.0.0.1:8732
```

Then run the node and synchronise.

```
systemctl enable octez-node.service
systemctl start octez-node.service
```

```
octez-client bootstrapped
```

The node was updating well over 10 blocks a minute. At the moment, Tezos produces 4 blocks a minute. It was able to catch up and the synchronisation took under five and a half hours. The time is dependent on how out of date the archive tarball is and the network speed.

We left the node running for a few days to see how it performed.

5.2.2 From a full node reconstruction

For this experiment, we first setup a full node, then we run the recovery process. This usually takes a lot of time. Firstly we setup and configure the node:

```
sudo systemctl stop octez-node
sudo su - tezos
rm -rf /var/tezos/node
mkdir -p /var/tezos/node
octez-node config init --data-dir /var/tezos/node \
            --network=mainnet \
            --history-mode=full \
            --net-addr="[::]:9732" \
            --rpc-addr=127.0.0.1:8732
```

Install a full snapshot. (The download took 50 minutes and the import took over 3 hours including the integrity check.)

```
wget -O /var/tezos/snap https://snapshots.eu.tzinit.org/mainnet/full
octez-node snapshot import /var/tezos/snap --data-dir /var/tezos/node
rm /var/tezos/snap
```

Then we rebuild the archive from the full node. The process cannot be done with the node running at the same time, so after the reconstruction the node must catch up with the network.

```
octez-node reconstruct --data-dir=/var/tezos/node
```

As we see below, we stopped the process. Had it finished we would have changed the configuration to be for archive:

```
octez-node config reset --data-dir /var/tezos/node \
            --network=mainnet \
            --history-mode=archive \
            --net-addr="[::]:9732" \
            --rpc-addr=127.0.0.1:8732
```

Then as root, restart the node:

```
sudo systemctl start octez-node
```

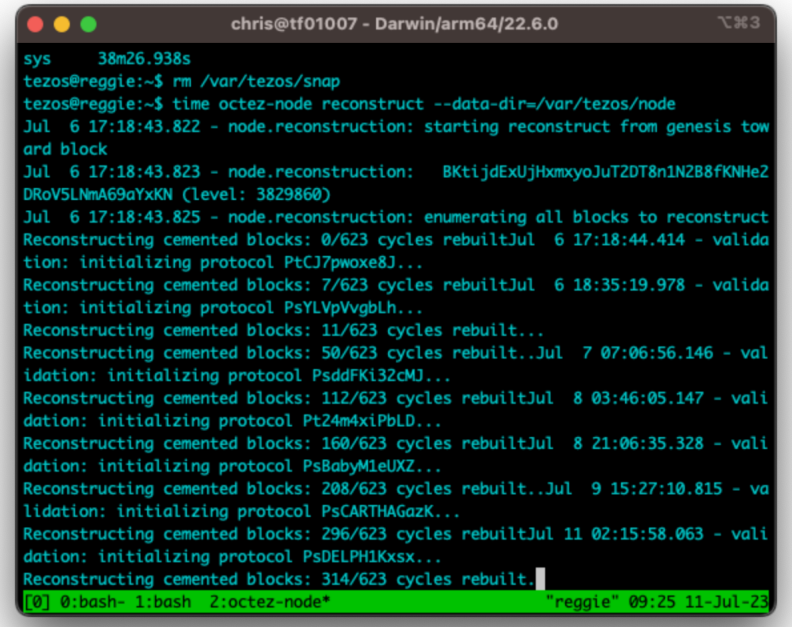

Figure 12: Reconstructing

5.3 Results

5.3.1 From a tar archive

It is possible to recover an archive node on a Raspberry Pi using the tar method and the machine can keep up with the network. The node was stopped at midday on 6th July. During the period, the node only became unsynced twice for under 20 seconds in each case.

```
Jul  2 14:24:32.949: synchronisation status: synced
Jul  2 18:14:13.654: synchronisation status: unsynced
Jul  2 18:14:32.235: synchronisation status: synced
Jul  5 15:25:16.309: synchronisation status: unsynced
Jul  5 15:25:23.607: synchronisation status: synced
```

In terms of performance, the system had used all the swap space but was able to cope maintaining the archive.

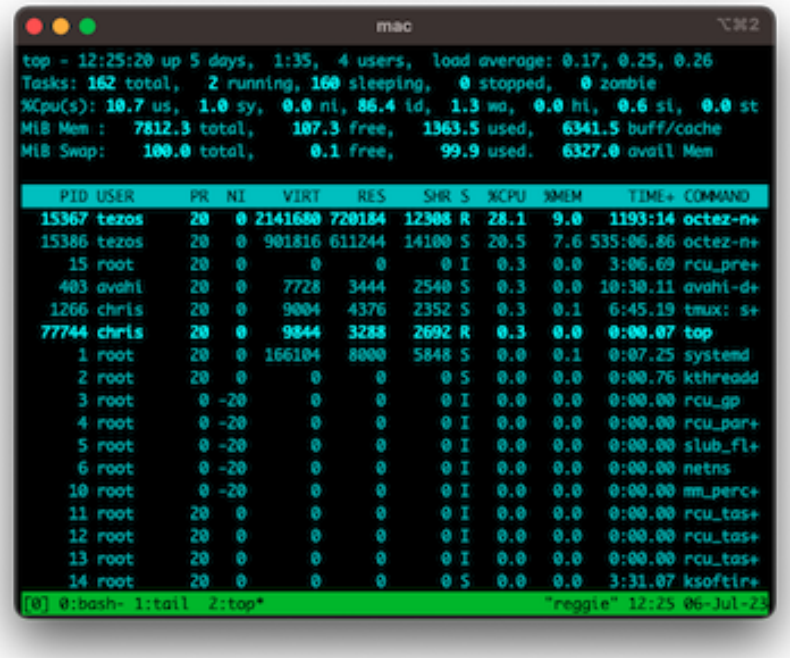

Figure 13: Top

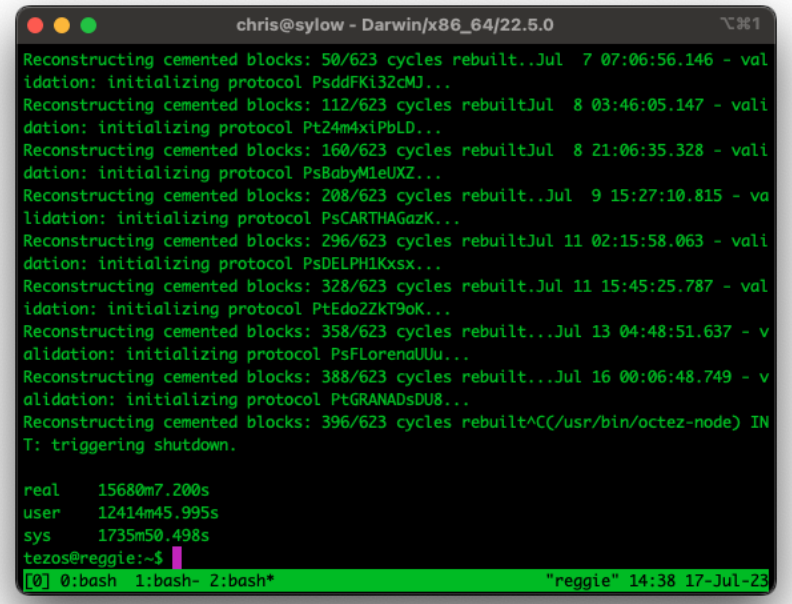

Figure 14: Interruption

5.3.2 From a reconstruction

I gave up. During the process, I had to move the machine and power it down. I stopped the process at cycle 396 (see above). To get to this point took almost 11 days.

I restarted the import and it picked up where it had left off. Between the 17th and 27th July it had only reconstructed 23 cycles. The remaining cycles would take longer to reconstruct because they are bigger. Tezos has increased the number of blocks per minute and the network has gained more traffic. So I decided to stop the process.

It's likely it would have taken until the end of August. Even then, after the reconstruction had finished, the node would need to catchup. The Raspberry Pi is the wrong machine to do this reconstruction. In fairness, there were no indications that the process would not have finished. Better to use a more powerful machine.

5.3.3 General comments

One consideration is disc space. It will be an issue on this machine soon:

```
chris@reggie:~$ df -h /var/tezos
```

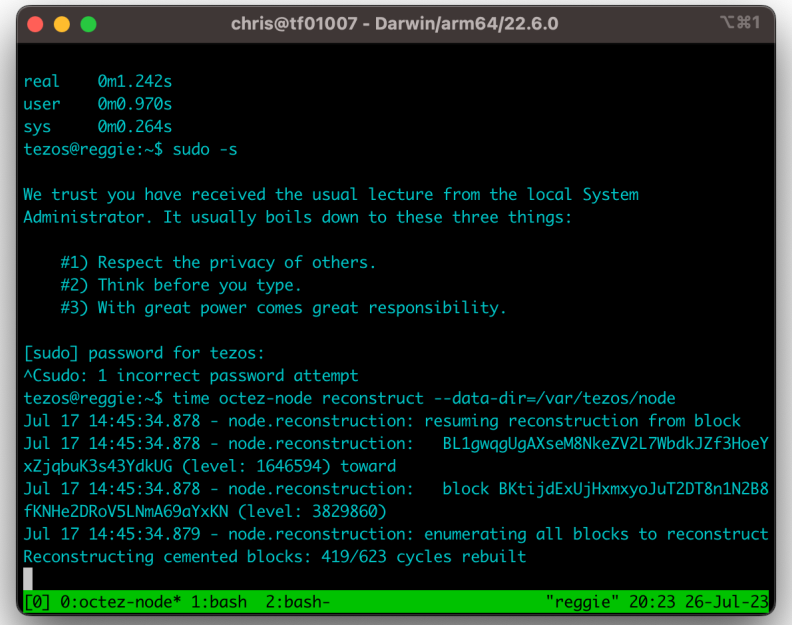

Figure 15: Getting impatient

```
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda1       1.8T  1.1T  694G  61% /var/tezos
```

5.4 Conclusion

A Raspberry Pi is capable of running an archive node. The best way to set it up is to download an archive tar from a snapshot site. It is potentially possible to recover an archive node from a full node, but it is better to use a more powerful machine.

6 Using the Octez Client

6.1 Aim

To check that the Raspberry Pi can operate as an Octez client. It is expected to work. All operations will be tested on Ghostnet.

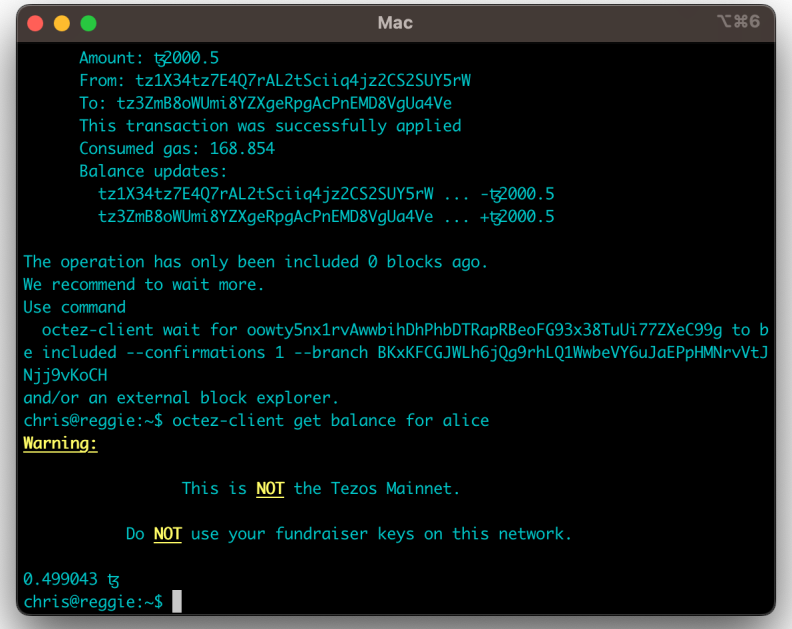

Figure 16: The Octez Client in action

6.2 Method

We connect to an RPC node on Ghostnet and perform operations. First we configure the client to use Marigold's Ghostnet RPC node and then generate a key.

```
octez-client --endpoint https://ghostnet.tezos.marigold.dev config update
octez-client gen keys alice
```

The key is generated and checked with `octez-client list known addresses`:

```
chris@reggie:~$ octez-client list known addresses
alice: tz1X34tz7E4Q7rAL2tSciiq4jz2CS2SUY5rW (unencrypted sk known)
chris@reggie:~$ octez-client get balance for alice
0 tz
```

```
chris@reggie:~$ octez-client get balance for alice
2001 tz
```

I went to the Ghostnet faucet and funded the wallet with 2001tz.

I delegated the amount to the TF baker on Ghostnet:

```
chris@reggie:~$ octez-client set delegate for alice to
    tz3ZmB8oWUmi8YZXgeRpgAcPnEMD8VgUa4Ve
Estimated gas: 170.868 units (will add 0 for safety)
Estimated storage: no bytes added
Estimated gas: 100 units (will add 0 for safety)
Estimated storage: no bytes added
Operation successfully injected in the node.
Operation hash is 'onxpwZZRmp7Th4mFis7AVhGSBgny5JxPQffkJagujLP9XcMAW17'
Waiting for the operation to be included...
Operation found in block:
    BLp9rGqPPPX2BfP1V1EehTTumtDg4EuUsct3x2geW1FdWNXq3b7 (pass: 3, offset:
    0)
....
The operation has only been included 0 blocks ago.
We recommend to wait more.
Use command
  octez-client wait for
      onxpwZZRmp7Th4mFis7AVhGSBgny5JxPQffkJagujLP9XcMAW17 to be included --
      confirmations 1 --branch
      BLqydoKBLyrNbWbLNWSrBXMHNGcEtJhzHZES6VU25RfdzaqpRCM
and/or an external block explorer.
```

I removed the delegation:

```
chris@reggie:~$ octez-client withdraw delegate from alice
Node is bootstrapped.
Estimated gas: 167.986 units (will add 0 for safety)
Estimated storage: no bytes added
```

```
Operation successfully injected in the node.
Operation hash is 'op3bikfKpq4Zp1DFPsrXx9vVBVDqMWRwwdFAVnLBVBvxa5xHhcf'
...
The operation has only been included 0 blocks ago.
We recommend to wait more.
Use command
  octez-client wait for
     op3bikfKpq4Zp1DFPsrXx9vVBVDqMWRwwdFAVnLBVBvxa5xHhcf to be included --
     confirmations 1 --branch
     BLuA1mWdpnzd75kbbtTwj6fKZ5BCFZedzzSuXdpoRgj4PDB4fAN
and/or an external block explorer.
```

And transferred the remaining funds to the TF baker:

```
chris@reggie:~$ octez-client transfer 2000.5 from alice to
   tz3ZmB8oWUmi8YZXgeRpgAcPnEMD8VgUa4Ve
Node is bootstrapped.
...
The operation has only been included 0 blocks ago.
We recommend to wait more.
Use command
  octez-client wait for
     oowty5nx1rvAwwbihDhPhbDTRapRBeoFG93x38TuUi77ZXeC99g to be included --
     confirmations 1 --branch
     BKxKFCGJWLh6jQg9rhLQ1WwbeVY6uJaEPpHMNrvVtJNjj9vKoCH
and/or an external block explorer.
chris@reggie:~$ octez-client get balance for alice
0.499043 tz
```

6.3 Results and Conclusion

The Octez client behaved as expected. The program does not need a huge amount of computing power. We will see in later sections, that the Octez client works fine with the Ledger connected via USB and with the Octez signer.

7 Running a Baker on Mainnet with a Ledger

7.1 Aim

To run a baker with appropriate security on mainnet. We will use a consensus key on a ledger.

7.2 Method

We follow the method in [5]. We will use a Ledger S+. Install the node and baker (as root):

```
dpkg -i octez-rpi-unoff-client_17.1-1_arm64.deb \
    octez-rpi-unoff-node_17.1-1_arm64.deb \
    octez-rpi-unoff-baker_17.1-1_arm64.deb
```

Then configure the node:

```
sudo su - tezos
rm -rf /var/tezos/node
mkdir -p /var/tezos/node
octez-node config init --data-dir /var/tezos/node \
            --network=mainnet \
            --history-mode=rolling \
            --net-addr="[::]:9732" \
            --rpc-addr=127.0.0.1:8732
```

Import a snapshot.

```
sudo su - tezos
wget -O /var/tezos/snap https://snapshots.eu.tzinit.org/mainnet/rolling
octez-node snapshot import /var/tezos/snap --data-dir /var/tezos/node
rm /var/tezos/snap
```

Start and synchronise the node (as root):

```
systemctl enable octez-node.service
systemctl start octez-node.service
octez-client bootstrapped
```

Now we attach the ledger to the USB port and configure it.

```
octez-client list connected ledgers
```

Using the ed25519 address, import the secret and setup for baking. Note I had used the Ledger on a test network previously, so needed to reset the High Watermark to 0. This counter protects the system from double baking.

```
octez-client import secret key ledger_tezos \
        "ledger://barry-goose-taming-terrence/ed25519/0h/0h"
octez-client setup ledger to bake for ledger_tezos --main-hwm 0
octez-client register key ledger_tezos as delegate
```

Ensure that `lq_vote` is set (we used *pass*) and `baking_key` is *ledger_tezos* in */etc/octez/baker.conf*, then start the baker:

```
systemctl enable octez-baker.service
systemctl start octez-baker.service
```

From the master wallet, we delegated consensus:

```
octez-client import public key consensuskey \
     unencrypted:edpktuQ....eHsy3TyW3
octez-client register key tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj as delegate
     \
    with consensus key consensuskey
```

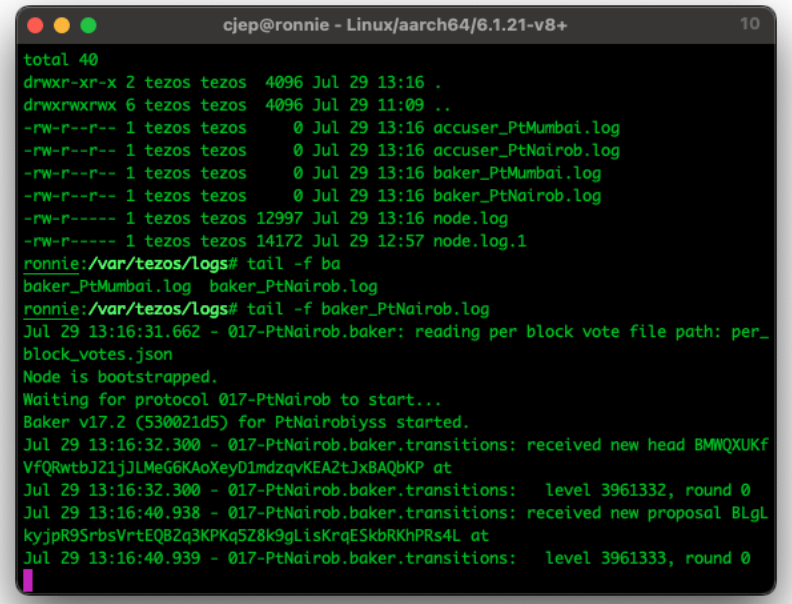

Figure 17: The baker starts

On the baker machine, we ran the baker as normal with the ledger key. Figure fig. 18 below shows the block explorer at the beginning of the delegation.

7.3 Results

The baker started baking at cycle 641. We decided to stop the process around cycle 650 by setting the deposits limit to zero and then waiting for the remaining cycles with rights to pass. The baker stopped baking at cycle 656.

We did this analysis during cycle 653. The baker had three opportunities to bake and successfully baked each time. The baker has one further opportunity in 655.

The baker also had many endorsement slots and this is where the story is different. The baker missed at least 5 slots in every cycle.

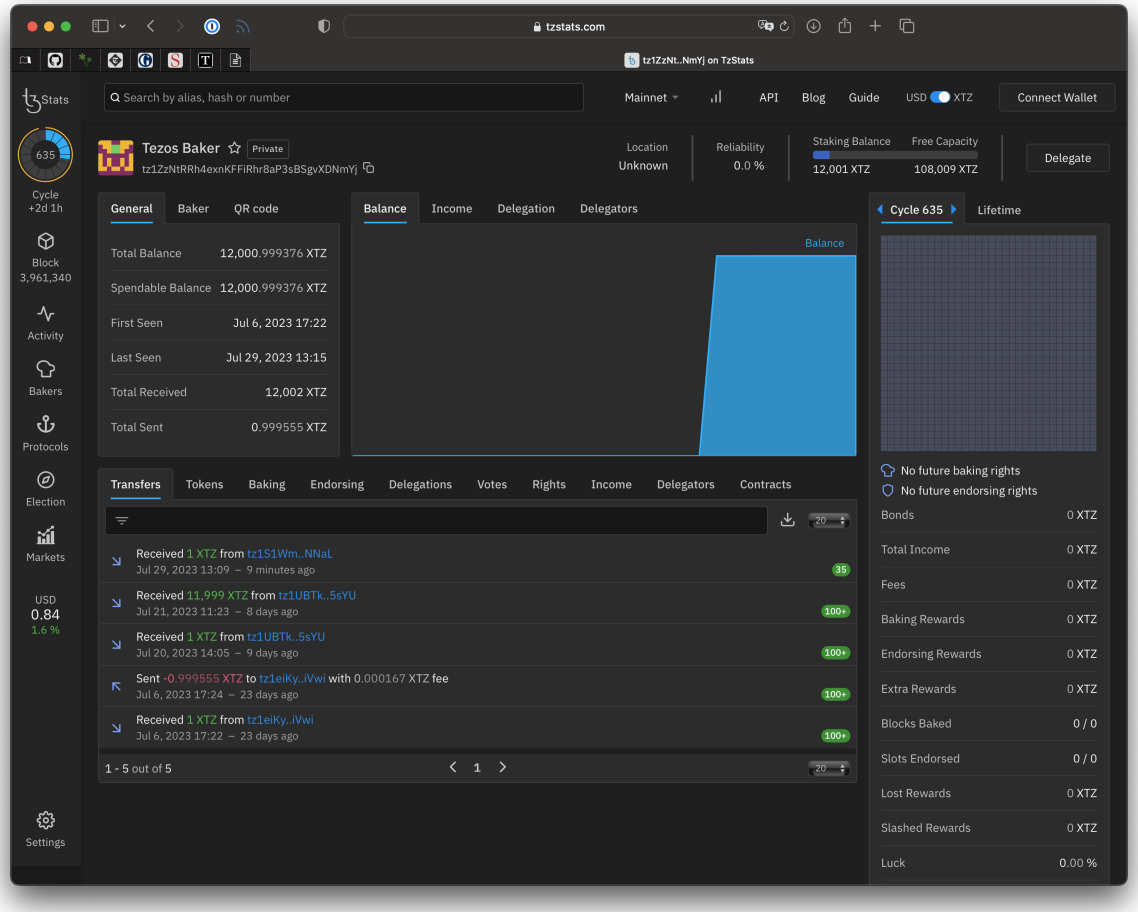

Figure 18: TzStats at the beginning

To analyse this further, we looked at the logs. The only baking errors we could find were as follows:

1. Consistency error near block 4104200 in cycle 644:

```
Aug 23 17:31:48.410 - 017-PtNairob.baker.transitions:   level 4104200,
    round 2
Aug 23 17:31:48.411 - 017-PtNairob.baker.scheduling: error while baking
Aug 23 17:31:48.411 - 017-PtNairob.baker.scheduling:   Error:
Aug 23 17:31:48.411 - 017-PtNairob.baker.scheduling:     The expected
    consistency invariant on locked values does not hold
```

2. Ledger transport errors near block 4118664 in cycle 644:

```
Aug 26 06:55:03.431 - 017-PtNairob.baker.transitions:   level 4118664,
    round 0
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions: unable to sign
    preendorsement for
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj --
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions:   Error:
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions:     Ledger Transport
    level error: hid_error is not implemented yet
Aug 26 06:55:04.586 - 017-PtNairob.baker.actions:
Aug 26 06:55:08.897 - 017-PtNairob.baker.actions: unable to sign
    endorsement for
Aug 26 06:55:08.897 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Aug 26 06:55:08.897 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj --
Aug 26 06:55:08.897 - 017-PtNairob.baker.actions:   Error:
Aug 26 06:55:08.897 - 017-PtNairob.baker.actions:     Ledger Transport
    level error: hid_error is not implemented yet
```

There were no errors in the regular node log.

To analyse this even further, we looked at a recent cycle 651 (Sep 12, 2023 19:27 - Sep 15, 2023 16:55):

During this cycle the baker missed endorsements for 17 blocks[2]. We examine the logs corresponding to the blocks. The missing slots are the number of endorsement slots missed for the block as a whole on the network.

Here *inj pre* and *inj end* are short for injected preendorsement and injected endorsement, respectively.

[2] During the analysis of this we discovered that tzkt reported the wrong block missed. It was out by 1.

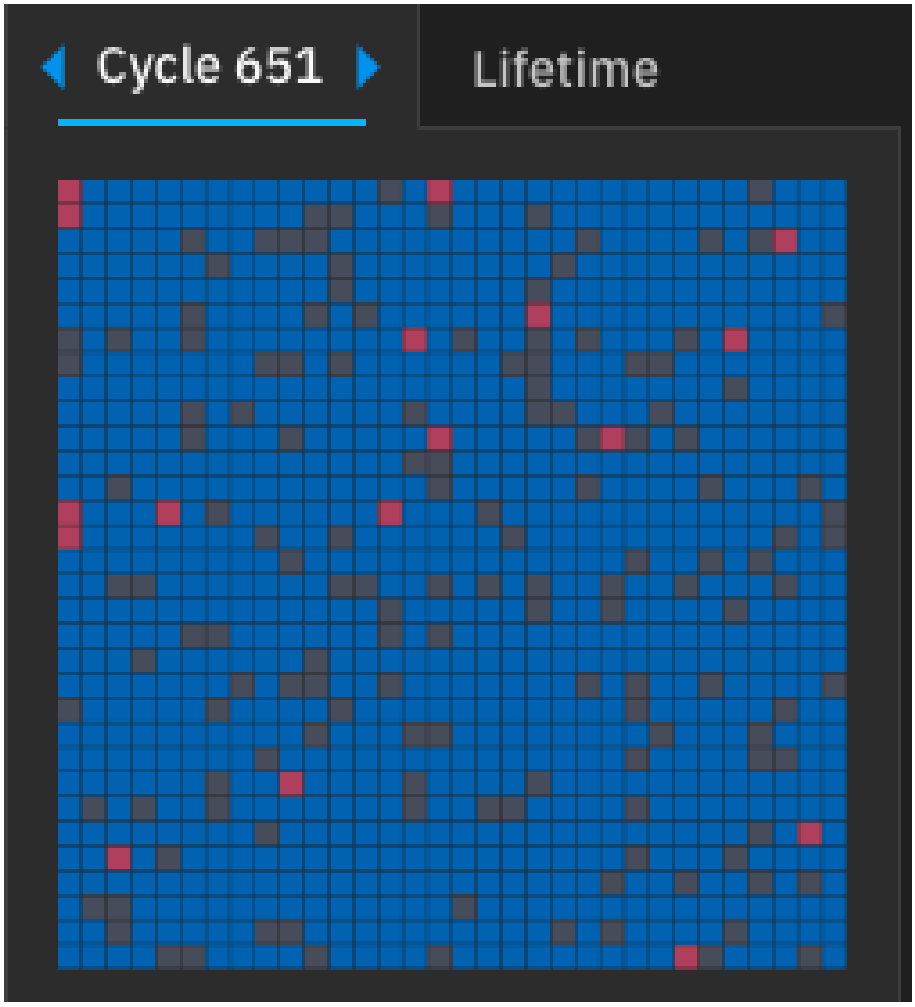

Figure 19: Cycle 651

Block missed	inj pre	inj end	missing slots	notes
4218885	yes	no	69	received a new head
4218909	no	no	19	no apparent effort to inject
4219096	yes	yes	11	baker thinks it injected
4219106	no	no	11	no apparent effort to inject
4220352	yes	yes	237	baker thinks it injected
4221143	yes	no	1513	a lot of slots missing
4223882	yes	yes	79	baker thinks it injected
4225746	yes	yes	89	baker thinks it injected
4226153	yes	yes	104	baker thinks it injected
4226566	yes	yes	105	baker thinks it injected
4228700	yes	yes	124	baker thinks it injected
4230305	yes	no	147	no effort to endorse
4232187	yes	yes	130	baker thinks it injected
4232804	yes	no	310	no effort to endorse
4233767	yes	yes	86	baker thinks it injected
4235276	no	no	833	no effort to inject, a lot of slots missing

For 8 of the blocks, the baker thought that it had injected the preendorsement and endorsement. In this case, the likely explanation for the miss is that the baker or node was not fast enough submitting the operations to the network.

Of the remaining 9, block 4218885 can be treated as an anomaly because a new head was received. Similarly, for blocks 4221143 and 4235276 other bakers were having trouble endorsing.

For two blocks, the baker preendorsed but did not log an endorsement. For blocks the remaining blocks there was no effort to inject anything. For the last block in the table, a lot of endorsement slots were missed on the network.

7.4 Conclusions

The Raspberry Pi together with a Ledger S+ is able to keep up almost fully with the Mainnet network. The two ledger errors we found are unexplained. Unfortunately there are misses in every cycle. We originally tried this experiment on Ghostnet and got similar results. It is entirely possible that it is the ledger that is the bottleneck and not the Raspberry Pi. However some bakers are successfully baking on PC hardware with a ledger and with no regular misses. In the next section we look at an alternative key signing method.

7.5 Appendix of log entries

7.5.1 Block 4218885

```
Sep 12 19:28:52.564 - 017-PtNairob.baker.transitions: received new
    proposal BL2Th3zEi7kFttPY7GZQok28Brjz3EJJswQ32xFjXGdc823ReA7 at
Sep 12 19:28:52.564 - 017-PtNairob.baker.transitions:   level 4218885,
    round 0
Sep 12 19:28:53.321 - 017-PtNairob.baker.actions: injected preendorsement
    oo5jAujcaUbE2uUvzfLQ9AVoKB4XFGbZKvT5pSXD7BfqHkk15TN
Sep 12 19:28:53.321 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 12 19:28:53.321 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4218885, round
Sep 12 19:28:53.321 - 017-PtNairob.baker.actions:   0
Sep 12 19:29:23.453 - 017-PtNairob.baker.transitions: received new head
    BL2Th3zEi7kFttPY7GZQok28Brjz3EJJswQ32xFjXGdc823ReA7 at
Sep 12 19:29:23.453 - 017-PtNairob.baker.transitions:   level 4218885,
    round 0
```

7.5.2 Block 4218909

```
Sep 12 19:37:56.407 - 017-PtNairob.baker.transitions: received new
    proposal BKtQU9Whea621yjbVyQQFAdkuwYRF25k3BXjdjDZA1Se4xwTuZc at
Sep 12 19:37:56.407 - 017-PtNairob.baker.transitions:   level 4218909,
    round 0
Sep 12 19:37:57.701 - 017-PtNairob.baker.transitions: received new head
    BKtQU9Whea621yjbVyQQFAdkuwYRF25k3BXjdjDZA1Se4xwTuZc at
Sep 12 19:37:57.701 - 017-PtNairob.baker.transitions:   level 4218909,
    round 0
```

7.5.3 Block 4219096

```
Sep 12 20:24:54.903 - 017-PtNairob.baker.transitions: received new
    proposal BLKt92MWVwUp57Kj8NkXExnkDKGUcXzT3C766MtdkHXxrSofjiA at
Sep 12 20:24:54.903 - 017-PtNairob.baker.transitions:   level 4219096,
    round 0
Sep 12 20:24:55.840 - 017-PtNairob.baker.actions: injected preendorsement
    npX32rLdnFmEeLHUmwJjLU1FY9Yw9bwNRGW3FUsxDvuErKi3kB
Sep 12 20:24:55.840 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 12 20:24:55.840 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4219096, round
Sep 12 20:24:55.840 - 017-PtNairob.baker.actions:   0
Sep 12 20:24:57.485 - 017-PtNairob.baker.actions: injected endorsement
    pHGB7uRYzKm7snAV4kgWRHfcQA23YxQUsjmeYPevTKzDpAFkKa for
Sep 12 20:24:57.485 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 12 20:24:57.485 - 017-PtNairob.baker.actions:   on behalf of
    z1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4219096, round
Sep 12 20:24:57.485 - 017-PtNairob.baker.actions:   0
```

7.5.4 Block 4219106

```
Sep 12 20:27:31.082 - 017-PtNairob.baker.transitions: received new
    proposal BL8MrBFFrBhheFNjyFyyjw63Ek9t2tGF95sm2fY1KQsANmrfdcQ at
Sep 12 20:27:31.082 - 017-PtNairob.baker.transitions:   level 4219106,
    round 0
Sep 12 20:27:33.169 - 017-PtNairob.baker.transitions: received new head
    BL8MrBFFrBhheFNjyFyyjw63Ek9t2tGF95sm2fY1KQsANmrfdcQ at
Sep 12 20:27:33.169 - 017-PtNairob.baker.transitions:   level 4219106,
    round 0
```

7.5.5 Block 4220352

```
Sep 13 01:43:11.266 - 017-PtNairob.baker.transitions: received new
    proposal BKz4sgYCat9ddJj4HcYaxJuurQqkxn7MQxrJAgXmBMBCyocVLEL at
Sep 13 01:43:11.266 - 017-PtNairob.baker.transitions:   level 4220352,
    round 0
Sep 13 01:43:13.273 - 017-PtNairob.baker.actions: injected preendorsement
    np19FukV8uqEAKN2MeGNUw9urQ5NqLA9aANZ3dspZnRzKZFbLV
Sep 13 01:43:13.273 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 13 01:43:13.273 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4220352, round
Sep 13 01:43:13.273 - 017-PtNairob.baker.actions:   0
Sep 13 01:43:16.324 - 017-PtNairob.baker.actions: injected endorsement
    ooHnvDQzn33BtD34oYSHoRZCPcTzkwSgVZeWNWRDY6rEqZPjPyv for
```

```
Sep 13 01:43:16.324 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 13 01:43:16.324 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4220352, round
Sep 13 01:43:16.324 - 017-PtNairob.baker.actions:   0
```

7.5.6 Block 4221143

```
Sep 13 05:09:24.688 - 017-PtNairob.baker.transitions: received new
    proposal BLkj
DgiB6cZ7ni7akhJbTse7poNvFQ3JmfPx43g6rK477sNAGrC at
Sep 13 05:09:24.688 - 017-PtNairob.baker.transitions:   level 4221143,
    round 0
Sep 13 05:09:26.597 - 017-PtNairob.baker.actions: injected preendorsement
    opLvDapxdahSxG7aA59Zw1JnVK1NWUGDYfWP7GxFpppMGrgWGQp
Sep 13 05:09:26.597 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 13 05:09:26.597 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4221143, round
Sep 13 05:09:26.597 - 017-PtNairob.baker.actions:   0
```

7.5.7 Block 4223882

```
Sep 13 16:51:40.005 - 017-PtNairob.baker.transitions: received new
    proposal BM4VnxQCZjcXPRPGrDrWHXnGSf2X9msY3Mzdyns7eghrkdKN6Rc at
Sep 13 16:51:40.006 - 017-PtNairob.baker.transitions:   level 4223882,
    round 0
Sep 13 16:51:42.297 - 017-PtNairob.baker.actions: injected preendorsement
    oorRddxDwgZYYf91W2xJ279VMo3AjJx4ieYQtZfjzrLMPfb8FQp
Sep 13 16:51:42.297 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 13 16:51:42.297 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4223882, round
Sep 13 16:51:42.297 - 017-PtNairob.baker.actions:   0
Sep 13 16:51:45.826 - 017-PtNairob.baker.actions: injected endorsement
    onoEsVTeWwVXgvmqJXYeU6eoTqBGnEMuqf6M5h6E3XHXTMxoh1K for
Sep 13 16:51:45.826 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 13 16:51:45.826 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4223882, round
Sep 13 16:51:45.826 - 017-PtNairob.baker.actions:   0
```

7.5.8 Block 4225746

```
Sep 14 00:43:00.210 - 017-PtNairob.baker.transitions: received new
    proposal BLYagwJhBoL4QbNjRbUbccMmNNTKUndrcCs9QrSSpHSSFB6g5Jd at
Sep 14 00:43:00.210 - 017-PtNairob.baker.transitions:   level 4225746,
    round 0
Sep 14 00:43:00.977 - 017-PtNairob.baker.actions: injected preendorsement
    oo5Bigfy8HPNzxUAgEc4jK54i1XFakVCZzzicS64AY3YZpVYY4M
Sep 14 00:43:00.977 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 00:43:00.977 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4225746, round
Sep 14 00:43:00.977 - 017-PtNairob.baker.actions:   0
Sep 14 00:43:06.163 - 017-PtNairob.baker.actions: injected endorsement
    opCmWBofbKEZMNkP5Q7AmSoythg6nXfNJVWo9rUQobpyJ8Swudb for
Sep 14 00:43:06.163 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 00:43:06.163 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4225746, round
Sep 14 00:43:06.163 - 017-PtNairob.baker.actions:   0
```

7.5.9 Block 4226153

```
Sep 14 02:25:31.282 - 017-PtNairob.baker.transitions: received new
    proposal BLhttLHM2SK6FtfPhyxhxCYk9VgR4ujnFtCBXLo3NTYqXnfT7RV at
Sep 14 02:25:31.282 - 017-PtNairob.baker.transitions:   level 4226153,
    round 0
Sep 14 02:25:33.132 - 017-PtNairob.baker.actions: injected preendorsement
    onhRmwo7xpueiFYsRUt7DooQiigadKUKzbiwPSEuYG1NvSaCMNz
Sep 14 02:25:33.132 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 02:25:33.132 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4226153, round
Sep 14 02:25:33.132 - 017-PtNairob.baker.actions:   0
Sep 14 02:25:36.688 - 017-PtNairob.baker.actions: injected endorsement
    onu1Tu6R8fhsVLm5Xm53gQshERXS57L4EoLBZAy6HmtnD7uh9Ya for
Sep 14 02:25:36.688 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 02:25:36.688 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4226153, round
Sep 14 02:25:36.688 - 017-PtNairob.baker.actions:   0
```

7.5.10 Block 4226566

```
Sep 14 04:09:55.566 - 017-PtNairob.baker.transitions: received new
    proposal BLssMEes1rRWBz2UwMBfAzvnJpBDnAk3DWE3BxuaJoVt173Pv6Z at
Sep 14 04:09:55.566 - 017-PtNairob.baker.transitions:   level 4226566,
    round 0
```

```
Sep 14 04:09:57.541 - 017-PtNairob.baker.actions: injected preendorsement
    oob7nQvVpJZ2rPVNKf9hurw1qKN9Z3UUCfnC3oUqAHxEzLBii25
Sep 14 04:09:57.541 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 04:09:57.541 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4226566, round
Sep 14 04:09:57.541 - 017-PtNairob.baker.actions:   0
Sep 14 04:10:01.708 - 017-PtNairob.baker.actions: injected endorsement
    onvkM36A6f2TaCfeFi9jq5QMDoXGM9rQEdpiSxWYy8hAWKb91Ma for
Sep 14 04:10:01.708 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 04:10:01.708 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4226566, round
Sep 14 04:10:01.709 - 017-PtNairob.baker.actions:   0
```

7.5.11 Block 4228700

```
Sep 14 13:12:14.461 - 017-PtNairob.baker.transitions: received new
    proposal BM95VtnZci5gdKRHySv3jZPoabhTNv47EMQajfJo6wsyCTQ5PA3 at
Sep 14 13:12:14.461 - 017-PtNairob.baker.transitions:   level 4228700,
    round 0
Sep 14 13:12:16.265 - 017-PtNairob.baker.actions: injected preendorsement
    oo1zYjBzdpfN22FRnnapaAki7wkmcY4szUEGi9Yiq8Aofd9VSbb
Sep 14 13:12:16.265 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 13:12:16.266 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4228700, round
Sep 14 13:12:16.266 - 017-PtNairob.baker.actions:   0
Sep 14 13:12:21.219 - 017-PtNairob.baker.actions: injected endorsement
    oo21hLm2U7YWEkwDeiwbMAa55eGcohvbpDcpU9Jc4PcunLec5oi for
Sep 14 13:12:21.219 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 14 13:12:21.219 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4228700, round
Sep 14 13:12:21.219 - 017-PtNairob.baker.actions:   0
```

7.5.12 Block 4230305

```
Sep 14 20:00:47.851 - 017-PtNairob.baker.transitions: received new
    proposal BLjUHTxk1f76d9ZPab2as7EDzKMCLHkHM8nMAtics4LrWJA1sem at
Sep 14 20:00:47.851 - 017-PtNairob.baker.transitions:   level 4230305,
    round 0
Sep 14 20:00:48.657 - 017-PtNairob.baker.actions: injected preendorsement
    onnfuJpnkNW8Q8JbNMsLaYBJhYBMKBFDDCGM2Nh66zq6pvAVJLM
Sep 14 20:00:48.657 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
```

```
Sep 14 20:00:48.657 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4230305, round
Sep 14 20:00:48.657 - 017-PtNairob.baker.actions:   0
```

7.5.13 Block 4232187

```
Sep 15 03:58:34.793 - 017-PtNairob.baker.transitions: received new
    proposal BLTWuKbK6acmigw4Nd1ime5G1HPbPoXGWGEd4QShbd7ceyixR4b at
Sep 15 03:58:34.793 - 017-PtNairob.baker.transitions:   level 4232187,
    round 0
Sep 15 03:58:35.548 - 017-PtNairob.baker.actions: injected preendorsement
    op89XwtaSYfhqF1oTLHKuR3YmXTsucfE5ohCQQyCgoDTwrKR6YS
Sep 15 03:58:35.548 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 15 03:58:35.548 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4232187, round
Sep 15 03:58:35.548 - 017-PtNairob.baker.actions:   0
Sep 15 03:58:39.032 - 017-PtNairob.baker.actions: injected endorsement
    ooNgq8TikZP4E2N8DQz3xhMy9e1x8SXUR9Gu3XXdR6sb2iWQAvZ for
Sep 15 03:58:39.032 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 15 03:58:39.032 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4232187, round
Sep 15 03:58:39.032 - 017-PtNairob.baker.actions:   0
```

7.5.14 Block 4232804

```
Sep 15 06:35:29.369 - 017-PtNairob.baker.transitions: received new
    proposal BM9newT9jZL6t9R148yuCKopma7VyQ6oR22gbBVEJRyUL9USuFW at
Sep 15 06:35:29.369 - 017-PtNairob.baker.transitions:   level 4232804,
    round 0
Sep 15 06:35:30.165 - 017-PtNairob.baker.actions: injected preendorsement
    onjvq2Wrd1a6Zj9mUMFBfqz4A7EpH4xDsLZS71SyqS1zKQryYUs
Sep 15 06:35:30.166 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 15 06:35:30.166 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4232804, round
Sep 15 06:35:30.166 - 017-PtNairob.baker.actions:   0
```

7.5.15 Block 4233767

```
Sep 15 10:38:31.346 - 017-PtNairob.baker.transitions: received new
    proposal BMWy
9ths8Fa8AK2yAVowbSvoDEDqiM5j5gpcWvUM7aSYr9A7Dfy at
```

```
Sep 15 10:38:31.346 - 017-PtNairob.baker.transitions:   level 4233767,
    round 0
Sep 15 10:38:32.132 - 017-PtNairob.baker.actions: injected preendorsement
    ooV7DABgg2NGobExAMMFUsuGVTsoVnWEoSXnYwxjDBhQyYq22tt
Sep 15 10:38:32.133 - 017-PtNairob.baker.actions:   for ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 15 10:38:32.133 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4233767, round
Sep 15 10:38:32.133 - 017-PtNairob.baker.actions:   0
Sep 15 10:38:37.855 - 017-PtNairob.baker.actions: injected endorsement
    opUHEL6M3idE9F76sZBKnkXNnt4sE38itD6Zpv5Bb8oFXmj1AuL for
Sep 15 10:38:37.855 - 017-PtNairob.baker.actions:   ledger_tezos (
    tz1VJ4DboDKchEQ2Pp3ikBtTn7E5WYbaQwXp)
Sep 15 10:38:37.855 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4233767, round
Sep 15 10:38:37.855 - 017-PtNairob.baker.actions:   0
```

7.5.16 Block 4235276

```
Sep 15 17:04:17.959 - 017-PtNairob.baker.transitions: received new
    proposal BM1E92ZNpa3BvC24XQM3ZbthT8E5iBTYne76xkF1ULMBnu8gBFA at
Sep 15 17:04:17.959 - 017-PtNairob.baker.transitions:   level 4235276,
    round 0
Sep 15 17:04:19.028 - 017-PtNairob.baker.transitions: received new head
    BM1E92ZNpa3BvC24XQM3ZbthT8E5iBTYne76xkF1ULMBnu8gBFA at
Sep 15 17:04:19.029 - 017-PtNairob.baker.transitions:   level 4235276,
    round 0
```

8 Running a Baker on Mainnet with a key on disc

8.1 Aim

To run a baker with with a local consensus key to determine if the ledger is the bottleneck.

Note that having such a consensus key is not recommended because if the security of the baker is compromised it is possible to drain the funds.

8.2 Method

We follow the method as per the last section, except that we generate a key on the hard disc and then delegate the consensus from the master baking key.

The baker key was `tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj` and the consensus key was `tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc`.

8.3 Results

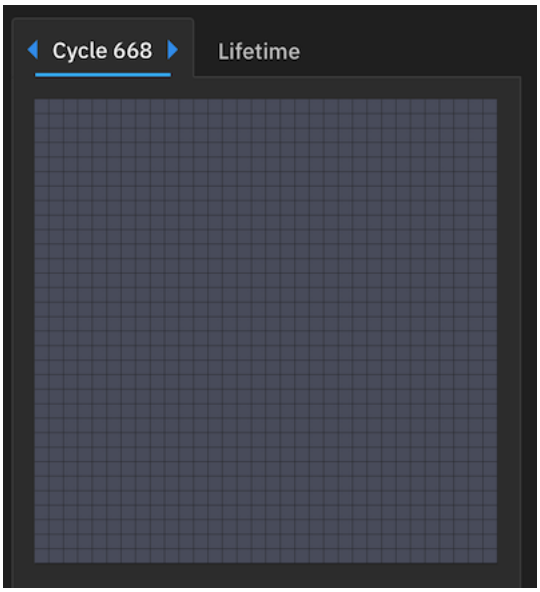

Figure 20: What happened in 668?

I expected the baker to perform better with the key directly on the disc. But there was minimal difference. The baker obtained rights in cycle 663 during which it missed 8 endorsements. There was similar performance in cycles 664 - 667. Curiously, the baker did not have any rights in cycle 668 and at first this looked like a bug (see conclusions). From 669 onwards baking rights resumed with similar performance. I set the deposits limit to 0 to withdraw from baking. At no point did the baker miss baking a block, just endorsements.

	671	12,100 XTZ	--	2	--	2	2,055	797.44 %	99.35 %
	670	12,097 XTZ	--	2	--	1	2,005	449.38 %	99.25 %
	669	12,084 XTZ	--	2	--	--	2,057	100.57 %	99.32 %
	668	12,084 XTZ	--	2	--	--	--	0.00 %	100.00 %
	667	12,084 XTZ	--	2	--	--	1,993	100.53 %	99.41 %
	666	12,084 XTZ	--	2	--	--	1,955	100.55 %	99.56 %

Figure 21: Baking Rights

To analyse this further we look at cycles 667. In the cycle we missed 10 endorsements which feels rather a lot.

Block missed	inj pre	inj end	missing slots	notes
4480041	yes	no	115	
4481039	no	no	64	no intent to endorse
4481046	no	no	63	no intent to endorse
4481059	no	no	30	no intent to endorse
4481060	yes	yes	41	not fast enough?
4481248	yes	no	33	
4481305	yes	yes	252	not fast enough?
4481907	yes	no	95	
4487720	yes	yes	80	not fast enough?

8.4 Conclusions

It would appear that the baker performed slightly better than with the ledger. But we fear that the law of small numbers is at play. Bakers do sometimes miss endorsements. In three of the cases, it looked as if the baker was not quite fast enough to submit its endorsements to the network. In other cases, it didn't seem to bother.

Pierre at Nomadic investigated the weird behaviour in cycle 668. He told me that it was due to the way I'd manipulated the key in earlier cycles. I'd set the deposit limits to zero and then later on reset them to bake again.

8.5 Appendix of log entries

8.5.1 Block 4480041

```
Oct 28 14:18:21.420 - 017-PtNairob.baker.actions: injected preendorsement
    opZznMyTYYXSpxpnHGqfnwU6ycZoozQBji8iVAs92rvMQE55jZm
Oct 28 14:18:21.420 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 14:18:21.420 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4480041, round
Oct 28 14:18:21.420 - 017-PtNairob.baker.actions:   0
```

8.5.2 Block 4481039

```
Oct 28 18:35:44.159 - 017-PtNairob.baker.transitions: received new
    proposal BLNpbopuqWYo4xpZ5XhrGmcrbEvnFq3F7YL73t6dPGTbDzKBTTq at
Oct 28 18:35:44.159 - 017-PtNairob.baker.transitions:   level 4481039,
    round 0
Oct 28 18:35:44.982 - 017-PtNairob.baker.transitions: received new head
    BLNpbopuqWYo4xpZ5XhrGmcrbEvnFq3F7YL73t6dPGTbDzKBTTq at
Oct 28 18:35:44.984 - 017-PtNairob.baker.transitions:   level 4481039,
    round 0
```

8.5.3 Block 4481046

```
Oct 28 18:36:37.957 - 017-PtNairob.baker.transitions: received new
    proposal BL7dmcgFVkC9y7Wpjw8PEc3CMky9SFWAWPNWABhoQJnnoiC5nUK at
Oct 28 18:36:37.957 - 017-PtNairob.baker.transitions:   level 4481046,
    round 0
Oct 28 18:36:44.083 - 017-PtNairob.baker.transitions: received new head
    BL7dmcgFVkC9y7Wpjw8PEc3CMky9SFWAWPNWABhoQJnnoiC5nUK at
Oct 28 18:36:44.083 - 017-PtNairob.baker.transitions:   level 4481046,
    round 0
```

8.5.4 Block 4481059

```
Oct 28 18:37:44.215 - 017-PtNairob.baker.transitions: received new
    proposal BLxYbJmcEZUUEGJPZg7t8hwiS4RXQ7kEAzbUw95iw4tr9LTNWcP at
Oct 28 18:37:44.215 - 017-PtNairob.baker.transitions:   level 4481059,
    round 0
Oct 28 18:37:45.656 - 017-PtNairob.baker.transitions: received new head
    BLxYbJmcEZUUEGJPZg7t8hwiS4RXQ7kEAzbUw95iw4tr9LTNWcP at
Oct 28 18:37:45.656 - 017-PtNairob.baker.transitions:   level 4481059,
    round 0
```

8.5.5 Block 4481060

```
Oct 28 18:37:48.232 - 017-PtNairob.baker.transitions: received new
    proposal BLAM
EiJcURdAfSKKZjXKbhmcD6UBHSXoGEGZSbtcJr4PbL3J2gW at
Oct 28 18:37:48.232 - 017-PtNairob.baker.transitions:   level 4481060,
    round 0
Oct 28 18:37:50.800 - 017-PtNairob.baker.transitions: received new head
    BLAMEiJcURdAfSKKZjXKbhmcD6UBHSXoGEGZSbtcJr4PbL3J2gW at
Oct 28 18:37:50.800 - 017-PtNairob.baker.transitions:   level 4481060,
    round 0
Oct 28 18:37:55.917 - 017-PtNairob.baker.transitions: received new
    proposal BLf5cxY5pcwK8tqDpPPMWP2oSLXz2e6KZ3pQGsnsg18yu8WQdyy at
```

```
Oct 28 18:37:55.917 - 017-PtNairob.baker.transitions:   level 4481060,
    round 1
Oct 28 18:37:55.937 - 017-PtNairob.baker.actions: injected preendorsement
    ooQrowS8egBZ1nhUF4W26fWemtbp5kheL2yR6p18aXXEPm15mm3
Oct 28 18:37:55.937 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 18:37:55.937 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481060, round
Oct 28 18:37:55.937 - 017-PtNairob.baker.actions:   1
Oct 28 18:38:01.222 - 017-PtNairob.baker.actions: injected endorsement
    op5Y8Re4rrEKDm4EUuCvYP7Wy2evh9SEaorZuMjjiyEo1c914np for
Oct 28 18:38:01.222 - 017-PtNairob.baker.actions:   bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 18:38:01.222 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481060, round
Oct 28 18:38:01.222 - 017-PtNairob.baker.actions:   1
```

8.5.6 Block 4481248

```
Oct 28 19:25:20.217 - 017-PtNairob.baker.transitions: received new
    proposal BMUuozcSzfHGdLMsZNmRtohCCo7r2YYPhE1r8DPH9sfD9HC2h5J at
Oct 28 19:25:20.217 - 017-PtNairob.baker.transitions:   level 4481248,
    round 0
Oct 28 19:25:20.444 - 017-PtNairob.baker.actions: injected preendorsement
    ooi2fMDxdP3ncNb5mV6tDpzcJQYBqKE43h82Pqov4BgUoFKKmK8
Oct 28 19:25:20.444 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 19:25:20.444 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481248, round
Oct 28 19:25:20.444 - 017-PtNairob.baker.actions:   0
Oct 28 19:25:49.872 - 017-PtNairob.baker.transitions: received new head
    BMUuozcSzfHGdLMsZNmRtohCCo7r2YYPhE1r8DPH9sfD9HC2h5J at
Oct 28 19:25:49.872 - 017-PtNairob.baker.transitions:   level 4481248,
    round 0
```

8.5.7 Block 4481305

```
Oct 28 19:40:21.783 - 017-PtNairob.baker.transitions: received new
    proposal BLwwfYTPFVQ3474ikJgnnALU9Sa7EypsjTtpazvqZRXTcsoyt1Q at
Oct 28 19:40:21.783 - 017-PtNairob.baker.transitions:   level 4481305,
    round 0
Oct 28 19:40:21.920 - 017-PtNairob.baker.actions: injected preendorsement
    onw8cUDEE1T46e3qjcSkgAMWEB2oDGB4hTXM3GKdashufHcHDvs
Oct 28 19:40:21.920 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 19:40:21.920 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481305, round
```

```
Oct 28 19:40:21.920 - 017-PtNairob.baker.actions:   0
Oct 28 19:40:36.323 - 017-PtNairob.baker.actions: injected endorsement
    onvZrjQvaKYGVofVi3hAno8tub5E1YJLH4xZba5boUE7hxwXs5f for
Oct 28 19:40:36.323 - 017-PtNairob.baker.actions:   bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 19:40:36.323 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481305, round
Oct 28 19:40:36.323 - 017-PtNairob.baker.actions:   0
```

8.5.8 Block 4481907

```
Oct 28 22:11:45.962 - 017-PtNairob.baker.transitions: received new
    proposal BM4Xn4dq37RmVpRQu7FWR1kM1Yb49ua67W2k1QPYXXeUVzhYF6k at
Oct 28 22:11:45.962 - 017-PtNairob.baker.transitions:   level 4481907,
    round 0
Oct 28 22:11:47.584 - 017-PtNairob.baker.actions: injected preendorsement
    opNR1vzCJn4Fvqqjnp1oFJnHbUenCB8prRa8TzeAg8drEHvhE6i
Oct 28 22:11:47.584 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 28 22:11:47.584 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4481907, round
Oct 28 22:11:47.584 - 017-PtNairob.baker.actions:   0
```

8.5.9 Block 4487720

```
Oct 29 21:41:53.206 - 017-PtNairob.baker.transitions: received new
    proposal BLQ2zNUBU6CW43DLe3jjeoZve6gzizGQHy1r4A4VMeSD7Wpy7ef at
Oct 29 21:41:53.206 - 017-PtNairob.baker.transitions:   level 4487720,
    round 0
Oct 29 21:41:55.004 - 017-PtNairob.baker.actions: injected preendorsement
    ooGchrUXSzdq8MNMWN88Gnx8vbfEd6eajK1VTBJxopQzBvoUL2J
Oct 29 21:41:55.004 - 017-PtNairob.baker.actions:   for bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 29 21:41:55.004 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4487720, round
Oct 29 21:41:55.004 - 017-PtNairob.baker.actions:   0
Oct 29 21:41:59.710 - 017-PtNairob.baker.actions: injected endorsement
    ont9dgbvu4cjuhDun7du47GgQf8QJPwjMRk3S621Fd8TLieXaEC for
Oct 29 21:41:59.710 - 017-PtNairob.baker.actions:   bakertest (
    tz1XEJY3Psjo5pS5i1y563nik6BvJ9b4L7dc)
Oct 29 21:41:59.710 - 017-PtNairob.baker.actions:   on behalf of
    tz1ZzNtRRh4exnKFFiRhr8aP3sBSgvXDNmYj for level 4487720, round
Oct 29 21:41:59.710 - 017-PtNairob.baker.actions:   0
```

9 Running a Baker on Ghostnet with a key on disc

9.1 Aim

To run a baker with with a local baking key on ghostnet to see if it performs better than the previous experiments. As we are running on a test network, we can safely keep the baking key on the baker.

9.2 Method

We repeat the same method as before. The baking key was `tz1TXjPtkCaynBpwQmVWHkDbRh1REN6A7z2x`.

9.3 Results

The baker started endorsing and baking in cycle 816 and we stopped baking in cycle 823. The baker did miss some endorsements but not as many as on mainnet.

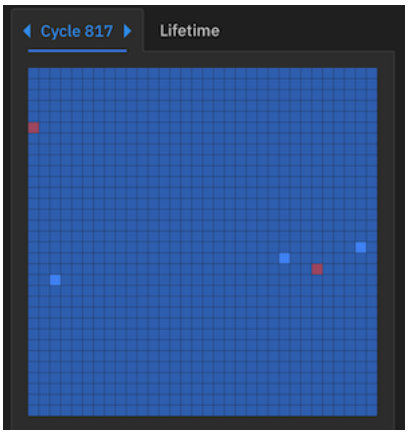

Figure 22: 817 sea of blue

cycle	misses
816	7
817	2
818	1
819	3
820	5

cycle	misses
821	3
822	3
823	6

Let's examine cycle 823 (blocks 4,579,329-4,587,520) where there are 6 misses.

Block missed	inj pre	inj end	missing slots	notes
4579333	yes	no	672	
4579364	no	no	228	didn't bother to inject?
4579365	no	no	222	didn't bother to inject?
4579366	no	no	378	didn't bother to inject?
4579367	yes	no	243	
4579688	no	no	225	didn't bother to inject?

9.4 Conclusion

The performance of a baker with the key directly on disc versus a ledger does not seem to be too different. It would likely to be better if observed over a longer time. The baker appeared to miss endorsements either due to speed or apathy. It's not clear why a baker daemon would exhibit apathy.

9.5 Log entries

```
Nov 21 01:18:42.774 - 017-PtNairob.baker.actions: injected preendorsement
    opGmUkXu9D9hbCoqx5SAz21oTjLgNX4rJhavohqTyZpcqtiyzBz
Nov 21 01:18:42.774 - 017-PtNairob.baker.actions:   for ghostnet-baker (
    tz1TXjPtkCaynBpwQmVWHkDbRh1REN6A7z2x) for level
Nov 21 01:18:42.774 - 017-PtNairob.baker.actions:   4579333, round 0

Nov 21 01:24:02.235 - 017-PtNairob.baker.transitions:   level 4579364,
    round 0
Nov 21 01:24:02.368 - 017-PtNairob.baker.transitions: received new head
    BLrcvYyFzgYLdBpsnfw8nixjJcMJs8n7LGobk8mYPCz6PL8RgJA at
Nov 21 01:24:02.368 - 017-PtNairob.baker.transitions:   level 4579364,
    round 0
```

```
Nov 21 01:24:02.530 - 017-PtNairob.baker.transitions: received new
    proposal BMSf3w1FKV2Ar3gd5JqNoaxcb1iuVxco2hFXMW1rUkcH9VbUaN4 at
Nov 21 01:24:02.531 - 017-PtNairob.baker.transitions:   level 4579365,
    round 0
Nov 21 01:24:04.296 - 017-PtNairob.baker.transitions: received new head
    BMSf3w1FKV2Ar3gd5JqNoaxcb1iuVxco2hFXMW1rUkcH9VbUaN4 at
Nov 21 01:24:04.296 - 017-PtNairob.baker.transitions:   level 4579365,
    round 0
Nov 21 01:24:04.384 - 017-PtNairob.baker.transitions: received new
    proposal BMX3fDCTFkbhui4AnRy5rNZt9wCHdQJ5noNTPKrrySazVRHHyH1 at
Nov 21 01:24:04.384 - 017-PtNairob.baker.transitions:   level 4579366,
    round 0
Nov 21 01:24:05.585 - 017-PtNairob.baker.transitions: received new
    proposal BLrkbb34euwqn14AD1fF6dq9X4NBjRv1oqpogdt55xuPwyE7BNn at
Nov 21 01:24:05.585 - 017-PtNairob.baker.transitions:   level 4579367,
    round 0
Nov 21 01:24:06.373 - 017-PtNairob.baker.actions: injected preendorsement
    opMhSFCG8sVFdUx5cFxWjbCQ8oXqe6GB352X8Eq6z5XPGWU1jkE
Nov 21 01:24:06.374 - 017-PtNairob.baker.actions:   for ghostnet-baker (
    tz1TXjPtkCaynBpwQmVWHkDbRh1REN6A7z2x) for level
Nov 21 01:24:06.374 - 017-PtNairob.baker.actions:   4579367, round 0

Nov 21 02:09:53.551 - 017-PtNairob.baker.transitions: received new
    proposal BKyWsa3p3j2CjphYTLxdsJBpSMYC7Pao3ttyBGaUzSqHHeBxPcs at
Nov 21 02:09:53.551 - 017-PtNairob.baker.transitions:   level 4579688,
    round 0
```

10 Running a Remote Signer

10.1 Aim

In this experiment, we tackle two things at once. We will run baker on ghostnet. We will use octez-signer on a second Raspberry Pi to hold the key.

10.2 Method

As we designed this experiment, we had come into the possession of a Raspberry Pi 5 (called Gerald). We used the Pi 5 as the baker and one of the Pi 4s as the signer.

We installed the Pi 4 with the octez-signer package and added a key for baking.

```
ronnie: {439} sudo su - tzsigner
tzsigner@ronnie:~$ octez-signer gen keys bakersignertest
tzsigner@ronnie:~$ octez-signer list known addresses
bakersignertest: tz1NfrwYK73UG6gHSj1xTztSkLSipX9TnMdT (unencrypted sk
    known)
```

We configured the signer service to protect against double baking and also to listen on the network interface. We editted */etc/octez/signer.conf* and changed these:

```
address=0.0.0.0
hwm_check=yes
```

Under normal circumstances we would have also added `magic_bytes="0x11,0x12,0x13"*` to allow only baking operations and prevent fund transfers. However we found a bug (see Conclusion).

We enabled the signer service.

```
systemctl enable octez-signer
systemctl start octez-signer
```

We setup the baker in the same way as the section above, but imported the key from the signer host (instead of a ledger or using one locally).

```
octez-client import secret key bakersignertest http://ronnie:6732/
   tz1NfrwYK73UG6gHSj1xTztSkLSipX9TnMdT
```

We funded the key using the faucet. The baker was started and once baking rights had been allocated, it started to endorse.

10.3 Results

The baker started endorsing in ghostnet cycle 859, see TzStats. It missed 4 endorsements in this cycle. In 860 there was a short outage of the baker. In cycle 862, it baked two blocks successfully.

The node crashed in cycle 865 due to a known bug. A restart fixed. This bug is not related to the Raspberry Pi.

```
Dec 27 09:43:01.667:   Error:
Dec 27 09:43:01.667:     {"Direct":["
   CoVPLA8DGe7MWoEabDoaycfR4sQDVgqGdRqZsWLR71o5pXah7Y7Z"
   ,395874863312,360]}: unknown inode key (find_value)
Dec 27 09:43:01.667:
Dec 27 09:43:01.668: worker crashed [validator-peer]:
Dec 27 09:43:01.668:   Error:
Dec 27 09:43:01.668:     {"Direct":["
   CoVPLA8DGe7MWoEabDoaycfR4sQDVgqGdRqZsWLR71o5pXah7Y7Z"
   ,395874863312,360]}: unknown inode key (find_value)
Dec 27 09:43:01.668:
```

Apart from a further outage (caused by me) in cycle 888, the Pi baker and endorsed almost all of its blocks. The worst case was 4 missed endorsements per cycle. We have not bothered to investigate

these given the frequency.

The signer was not loaded:

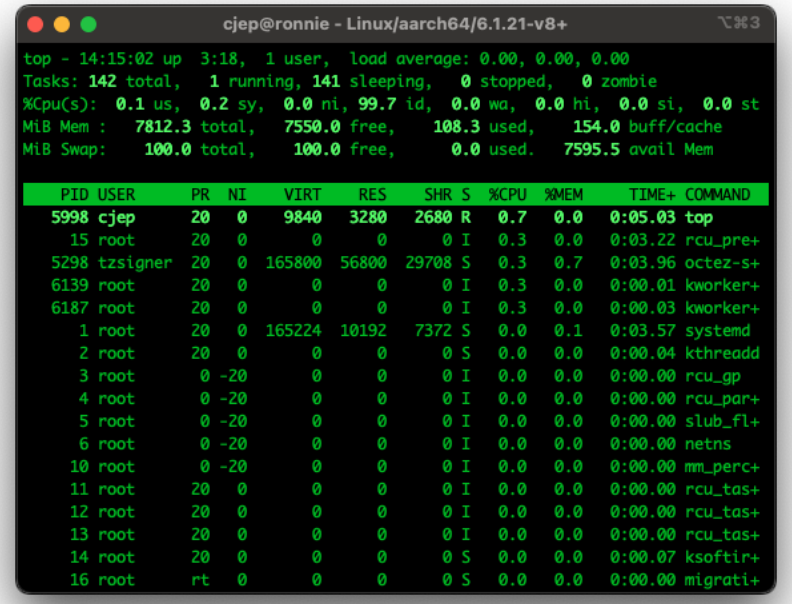

Figure 23: Signer Load

10.4 Conclusions

Although this test is somewhat skewed by the fact that we are using a fast Pi 5 to bake, the conclusion is that the Raspberry Pi 4 is more than adequate to act as a remote signer in a home situation. The results were better than our other tests, but we must be careful because the Pi 5 is involved and this is twice as fast as the Pi 4.

Additionally, if the Pi was setup without remote logins and with an encrpyted filesystem to hold the keys, it would be a cheap substitute for a hardware security module. The user would have to type a password into the Pi at boot, but this is a feasible use case. The memory footprint of the Signer is low and one could get away with running it on a 4GB machine.

We did not setup protection from funds transfers. In fact, we found a bug - magic byte protection was not working correctly. This has been fixed recently in Octez.

11 Simple Remote Signer load test

11.1 Aim

To see if the remote signer will perform under load.

11.2 Method

With the same setup as the previous chapter, we ran a hard loop calling the remote signer from the baking machine:

```
while :; do octez-client sign bytes 0x03 for bakersignertest; done
```

We did not attempt to overload the Pi with parallel requests.

11.3 Results

The Pi was more than capable of responding to a signing request. In fact the request was only marginally slower than having the key locally. The signer can respond within 1 second and this is more than fast enough to support the Tezos blockchain.

11.3.1 Remote key

```
tezos@gerald:~$ time octez-client sign bytes 0x03 for bakersignertest
Signature: edsigtnPqXv4YryLvXBHxXZgRh1LUMJdPTAV9x6iMPSRV...
   TmdHF2SvfdDstTxVA8phFux1Syx
real    0m0.916s
user    0m0.813s
sys 0m0.077s
```

11.3.2 Local key

```
tezos@gerald:~$ time octez-client sign bytes 0x03 for bakersignertest2
Signature: edsigtnPqXv4YryLvXBHxXZgRh1LUMJdPTAV...A8phFux1Syx

real    0m0.895s
user    0m0.814s
sys 0m0.065s
```

11.4 Conclusion

Although we did not load test the signer with parallel signs, it is clear that the signer code is fast enough on a Raspberry Pi 4 to support current Tezos network operations. The block time is 15 seconds currently and will be reduced to 8 seconds in a forthcoming release.

12 Running a VDF service

12.1 Aim

To see if the Raspberry Pi can effectively run a VDF service. We expect that this will not work due to memory usage. The Raspberry Pi was on the wireless network for this test.

12.2 Method

We follow the method in [6]. Install the node, baker and VDF packages (as root):

```
dpkg -i octez-rpi-unoff-client_17.1-1_arm64.deb \
    octez-rpi-unoff-node_17.1-1_arm64.deb \
    octez-rpi-unoff-baker_17.1-1_arm64.deb \
    octez-rpi-unoff-vdf_17.1-1_arm64.deb
```

Setup the node for mainnet.

```
sudo su - tezos
rm -rf /var/tezos/node
mkdir -p /var/tezos/node
octez-node config init --data-dir /var/tezos/node \
            --network=mainnet \
            --history-mode=rolling \
            --net-addr="[::]:9732" \
            --rpc-addr=127.0.0.1:8732
```

Install a rolling snapshot. (This took 72m including the integrity check.)

```
sudo su - tezos
wget -O /var/tezos/snap https://snapshots.eu.tzinit.org/mainnet/rolling
octez-node snapshot import /var/tezos/snap --data-dir /var/tezos/node
rm /var/tezos/snap
```

Start and synchronise the node (as root):

```
systemctl enable octez-node.service
systemctl start octez-node.service
```

```
octez-client bootstrapped
```

Start the VDF daemon and observe.

```
systemctl enable octez-vdf.service
systemctl start octez-vdf.service
tail -f /var/log/tezos/vdf_PtNairob.log
```

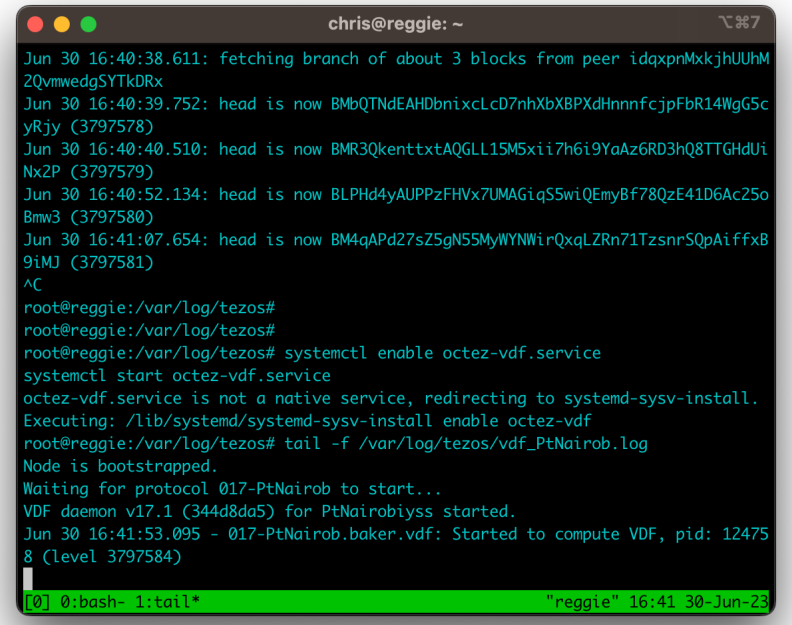

Figure 24: Running VDF

The daemon started with around 2.2GB of resident memory.

12.3 Results

I left the VDF daemon running over night and came back to an almost frozen system. It was able to update its top screen for a brief instant but after that is was unresponsive.

I had to power cycle the machine to recover.

Note that it was possible to sync the node on the wireless network.

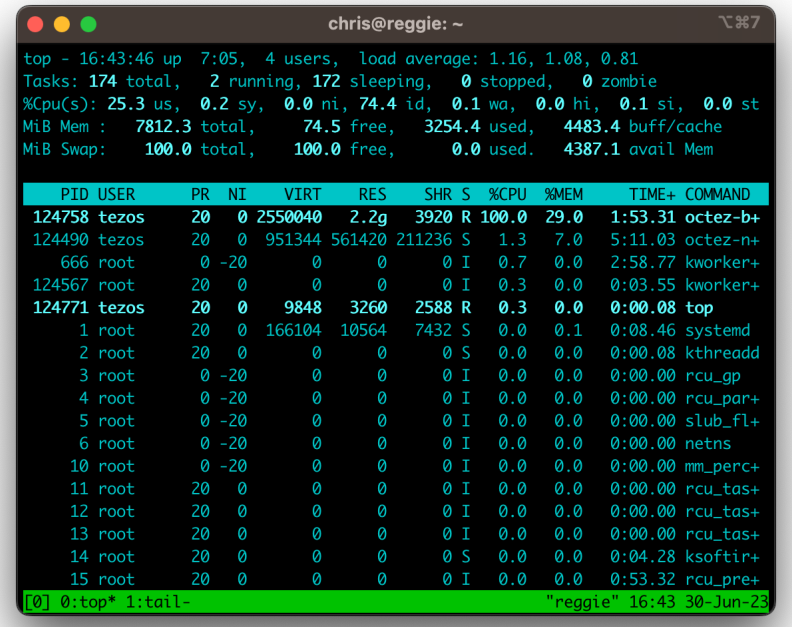

Figure 25: Initial Top results

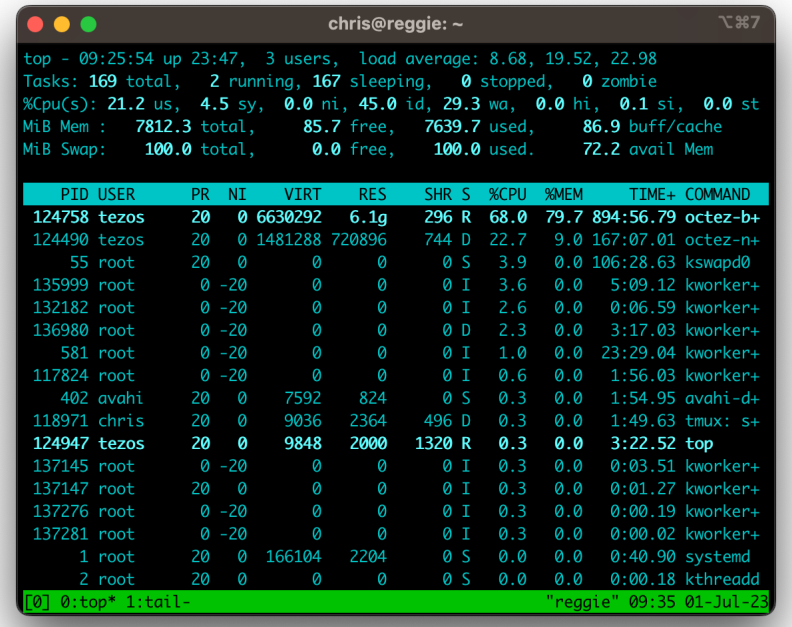

Figure 26: Final Top screen

12.4 Conclusion

As expected, it is not practical or possible to run the VDF service on a Raspberry Pi on mainnet. There is not enough memory.

13 Running a Smart Rollup Node

13.1 Aim

To join the Etherlink Minimum Viable Product test Smart Rollup. We will use a smart rollup node on Ghostnet as an operator. We will not attempt to run a full Etherlink EVM stack.

13.2 Method

We upgraded all the software to version 18.1. We setup a rolling node on the Raspberry Pi 4 and additionally installed the octez-smartrollup package. We reused the baker key which had over 10000tz available for a Smart Rollup bond. The key was `tz1TXjPtkCaynBpwQmVWHkDbRh1REN6A7z2x` .

```
octez-smart-rollup-node init operator \
                config for sr1HFDt5ZwBVcXTgLA4wQ9vtwMH7EKU5vMFr with
                   operators ghostnet-baker \
                        --rpc-addr 0.0.0.0 \
                        --history-mode archive \
                        --data-dir /var/tezos/smartrollup
```

We setup the Smart Rollup node with a copy of the data from one of the Tezos Foundation operator nodes. Instead of using the start up scripts, we ran the node by hand and observed the logs:

```
/var/tezos/src/tezos/octez-smart-rollup-node -E http://localhost:8732 run
   \
    --data-dir /var/tezos/smartrollup
```

The Pi started by converting the node directory to a new format and then synced with the rollup.

The machine's RAM was almost used up in full:

13.3 Results

Our 8GB Raspberry Pi 4 coped fine on the test network, but both the layer 1 node and the smart rollup node occupied all of the memory. In production, one would run these separately.

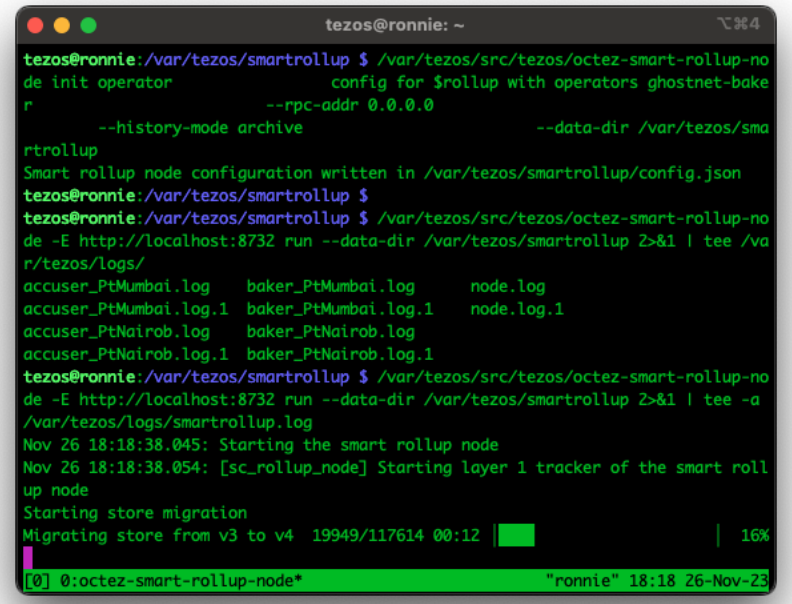

Figure 27: Memory

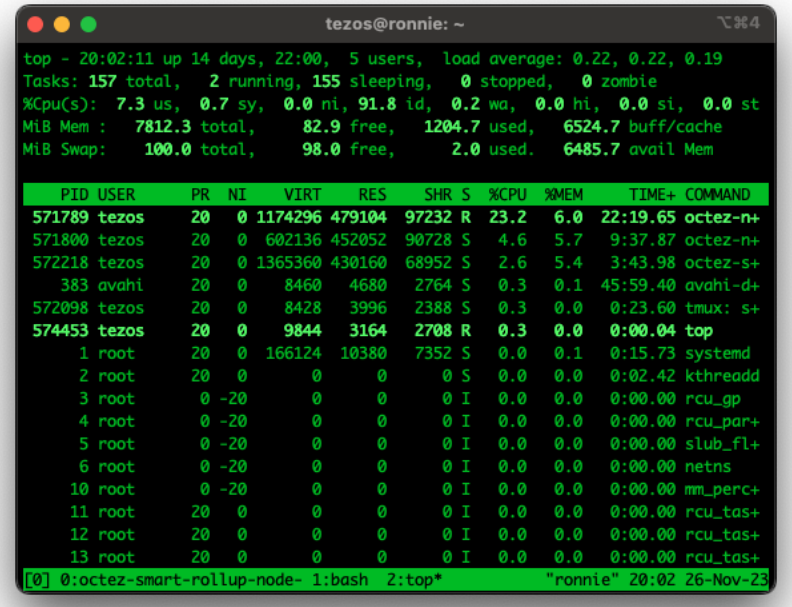

Figure 28: Memory

13.4 Conclusion

The recommended memory for an Etherlink Operator node is at least 32GB of RAM. Additionally it needs 1TB of available disc space. The disc space is not a problem for the Pi but the memory is. As I write this in January 2024, the Smart Rollup directory on the MVP is just under 15GB. We have not reached production load yet.

Although the Raspberry Pi coped, one would be better off with a machine with at least 16GB of RAM. It's unknown how the Pi would cope on the production Etherlink on mainnet. The production rollup is likely to be much busier. It will be worth a revisit when the time comes. We will mark this test as an amber to be risk averse.

As I write this, Tezos Foundation has launched a snapshot service for Etherlink. This makes is easier to setup nodes with an initial data set.

14 Acknowledgements

The Tezos Foundation paid for the equipment and kindly provided a small loan. This made testing on mainnet much easier. Also many thanks are due to the following (Slack and Twitter handles):

- pirbo (Pierre) for rescuing Nairobinet when my ledger S+ took it out during earlier testing
- memforget (Emma) for discussions about Orange Pis
- beatkalipska (Beata) for discussions about Raspberry Pis.
- TezberryPie continues to bake on the Orange Pi and has provided good insights on the Slack channels
- V for providing first-hand experience of baking on Raspberry Pi

14.1 What happened to Ronnie and Reggie (and Gerald)

No Raspberry Pi equipment was harmed in this experiment. They are safe.

Ronnie will become a development machine for NetBSD/arm64.

Reggie continues to archive mainnet. He made a brief appearance on the cofounder's twitter account.

Gerald continues to build software packages for Octez and will archive mainnet. Although he is considering retirement in the retro arcade games market.

Unfortunately the Ledger equipment was not so lucky. In early experiments we managed to burn out a Ledger S+ and had to replace it. We will remember them.

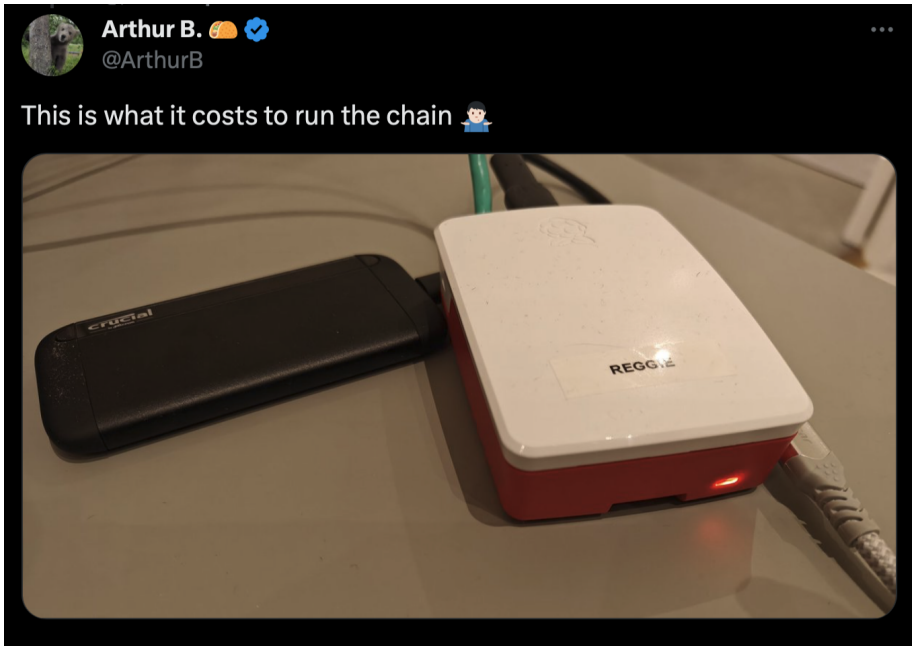

Figure 29: Arthur's Tweet

15 References

[1] https://tezos.gitlab.io/, Nomadic Labs *et al.*

[2] https://gitlab.com/tezos/tezos

[3] https://chrispinnock.com/tezos/packages/, Chris Pinnock, 2023

[4] https://chrispinnock.com/tezos/node/, Chris Pinnock, 2022

[5] https://chrispinnock.com/tezos/baker/, Chris Pinnock, 2022

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