Raspberry Pi SDCard Burner for Building Cloud and Compute Clusters

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***Abstract*—To create a cluster from Rasberry Pi's one needs to either use a headless setup or burn a number of SDC cards. Typically after the burning of SDCards, we are faced with additional setup steps. However these steps can be simplified while assuring that the SDCard is modified after the burning with ssh enabled, a public key injected, a unique hostname assigned, and a network address specified. This command is naturally also important in case we need to re-burn a card in case a card would become bad or the OS on it for some reason corrupted. While attaching a multi-card USB writer it is possible to write multiple cards at the time one needs to switch cards into a single card writer.**

I. Introduction

The Rasperry Pi provides to the community a cheap platform with the ability to expose Lunix and other operating systems to the masses. Du to its cost point it is easy to buy a PI and experiment with it. As such this platform has been ideal to lower the entry barrier to advanced computing from the university level to highschool and middle school and even elementary school. However the PI has also been used by universities and even national labs. Due to its availability iand is convenient accessibility is has become a staple of our educational pipeline.

Due to its price point the PI can also be used to build cheap clusters putting forward a hardware platform ideal for experimenting with issues such as networking and cluster management as educational tool. Many such efforts exist to use a PI as a cluster environment

TODO: add links here

There are a variety of administrative tasks that need to be conducted to allow such clusters to be put in place. This not only includes the creation of a physical space for the cluster, but also the ability to initialize such a cluster with software.

There are a number of different approaches to placing software for clusters on the Pi. IN general we distinguish the following setups PIXE boot and OS preloaded mode on the SD Cards.

II. Boot Configuration Methods

We review a number of configuration methods including setups know under the terms *headless*, *network booting*, and *booting form SDCards* and describe them in more detail next.

A. Headless

Under headless mode we understand the the Pi can be set up without the ability to have a monitor. The setup assumes that you have another computer from which you can log into the Raspberry. For this to work the PI and the computer must be on the same network. THis could be a wired or wireless connection. The most common setup discussed in the community is the wireless setup. Here one needs to modify the `/etc/wpa_supplicant/wpa_supplicant.conf` file and enter the `ssid` and the `password` of the network (see Lst. 1). This can be accomplished by changing the file on the SDCard.

Listing 1 wpa_supplicant.conf

```
country=us
update_config=1
ctrl_interface=/var/run/wpa_supplicant

network={
 ssid="<Name of your WiFi>"
 psk="<Password for your WiFi>"
 }
```

In addition we need to add the ability to remotely login with ssh. To do so we just have to place the file `ssh` ino the boot folder.

More information about this method can be found at

- https://www.raspberrypi.org/documentation/configuration/wireless/headless.md

B. Network Booting or PXE Boot

The abbreviation PXE stands for Pre-boot eXecution Environment and is associated with the netwrok booting

process of clients that boot from a server reachable via the network

In network booting we boot the PI from a server that contains all important OS information. One of the Pi's in the cluster (or other computer in the same network) needs to be set up as a DHCP/TFTP server.

This is typically a bit more complex, but can be scriptes entirely so that you could convert a freshly installed PI into such a server.

More information about this is available at

- https://www.raspberrypi.org/documentation/hardware/raspberrypi/bootmodes/net_tutorial.md
- https://www.raspberrypi.org/documentation/hardware/raspberrypi/bootmodes/net.md

In addition to setting up the server, each Pi must be set up as a client. On each PI we need to install a number of tools and services that interact with the server. THe boot process will take a significant amount of time and we need to be careful not too have too many Pi's in boot mode so the network is not overloaded.

C. Boot From a SDCard

The most common method the boot a PI is to have the operating system burned on the SDCard. In other methods we still have to have an SDCard or conduct modifications on the OS prior to us using an alternative method. Thus you will see that it is convenient to be able to write SDCards en-mass and make modifications on them to support the one or the other install method.

Hence if we had a convenient tool that allows us to not only burn the OS, but place important information on the SDCard before we boot, this will significantly reduce our setup time and also free the network from unnecessary traffic during the boot process of many PI's at once. This motivates our work and we deliver and describe our convenient command line tool to make such SDCards available through simple command interactions.

D. Other Solutions

Other solutions that we will expand upon in more detail in a future version of this paper include:

- PiServer: https://www.raspberrypi.org/blog/piserver/
- Boot from EEPROM (PI4): https://www.raspberrypi.org/documentation/hardware/raspberrypi/booteeprom.md
- Boot from USB

III. INTEGRATE FROM HERE ON

To create a cluster from Raspberry Pi's one needs to either use a headless setup or burn a number of SDC cards. Typically after the burning of SDCards, we are faced with additional setup steps. However these steps can be simplified while assuring that the SDCard is modified after the burning with ssh enabled, a public key injected, a unique hostname assigned, and a network address specified. This command is naturally also important in case we need to re-burn a card in case a card would become bad or the OS on it for some reason corrupted. While attaching a multi-card USB writer it is possible to write multiple cards at the time one needs to switch cards into a single card writer.

IV. Overview

`cm-burn` is a program to burn many SD cards for the preparation of building clusters with Raspberry Pi's. The program is developed in Python and is portable on Linux, Windows, and OSX. It allows users to create readily bootable SD cards that have the network configured, contain a public ssh key from your machine that you used to configure the cards. The unique feature is that you can burn multiple cards in a row. tem A sample command invocation looks like Lst. 2:

Listing 2 Command line invokation

```
cm-burn --name  red[5-7] \
        --key ~/.ssh/id_rsa.pub \
        --ips 192.168.1.[5-7] \
        --image 2018-06-27-raspbian-stretch
```

This command creates 3 SD cards where the hostnames `red5`, `red6`, `red 7` with the network addresses `192.168.1.5`, `192.168.1.6`, and `192.168.1.7`. The public key is added to the authorized_keys file of the pi user. The password login is automatically disabled and only the ssh key authentication is enabled.

V. Process

The process of the burn is as follows.

1. start the programm with the appropriate parameters the program will ask you to place an SD Card in the SD Card writer. Place it in
2. the specified image will be burned on the SD Card
3. next the SD Card will be mounted by the program and the appropriate modifications will bbe conducted.
4. after the modifications the SD Card will be unmounted
5. you will be asked to remove the card
6. if additional cards need to be burned, you will go to step 2.

In case a SD Card of a PI in the cluster goes bad, you can simply burn it again by providing the appropriate parameters, and just print the subset that are broken.

VI. Setting up a Single Large Cluster with cm-burn

`cm-burn` will setup a simple network on all cluster nodes configured. There are different models for networking configuration we could use. However we have decided for one that allows you to interface with your local Laptop to the cluster via Wifi. The setup is illustrated in Fig. 1

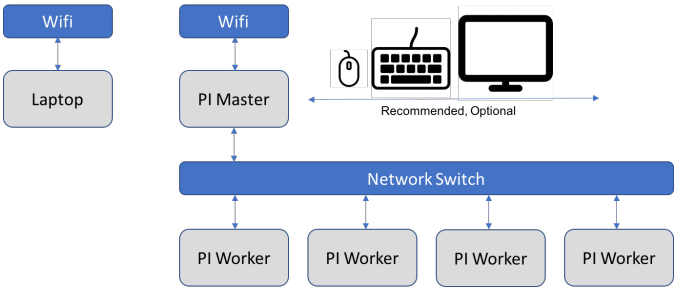


Figure 1: Network of a Raspberry Pi cluster

Figure: Networking

We assume that you have used cm-burn to create all SD cards for the Pi's. One of the Pi's is specially configured with the command

```
cm-burn --master red01
```

Manual page Lst. 3.

Listing 3 Creating a master

```
put the manual page here
```

The SD Card in the SD Card writer will be configured as a `master`. If the name does not match it will be configured as a worker. Only the `master` is connected with the Wifi network. All other nodes rout the internet connection through the master node. As the `master` node is on the same Wifi network as the laptop you can login to the 'master' node and from there log into the workers. To simplify access you could even setup ssh tunneled connections from the Laptop via the master. But this is left up to you if you wish.

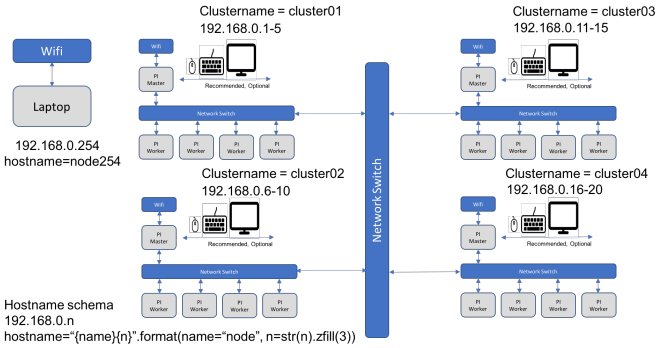
As a result you will be able to login on each of the machines and execute commands such as

```
sudo apt-get update
```

Certainly you can even have a much simpler setup by just attaching a keyboard, mouse and monitor/TV to your `master`. This will allow you to directly work on the master node, not needing any additional hardware.

A. Setting up a Cluster of Clusters with cm-burn

To integrate the clusters into a single network, we need a switch or combination of switches to which we connect the clusters. This is depicted in the Figure Cluster of Clusters



Each cluster is naemed cluster01-clusterNN. The hostnames are node followed by 3 zeros padded with the node number There is a correlation between the cluster number and the node numbers in the following interval

a cluster has the nodes

```
[(clustername - 1) * 5 + 1, (clustername - 1) * 5 + 5]
```

For convenience we will be also enabeling a cluster burn logic, that burns all images for a given cluster

cm-burn –workers=5 –name=cluster –nodes=nodes –id=3

B. Prerequisits

1) Raspberry Pi: We assume that you have set up a raspberry pi with the newest raspbian OS. We assume that you have changed the default password and can log into the pi.

We assume you have not done anything else to the OS.

The easiest way to duplicate the SD card is simply to clone it with the build in SD Card copier. This program can be found in the menu under Accessories.

Figure: SD Card Copier

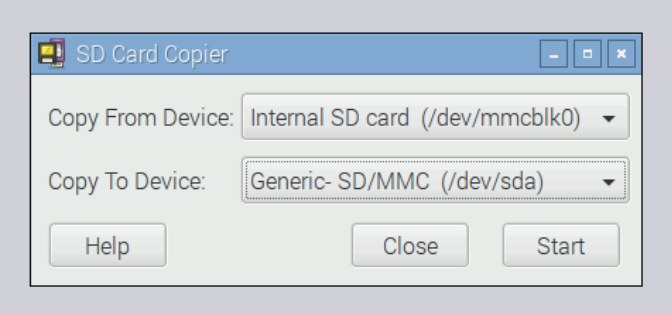


Figure 2: SD Card Copier

This program will copy the contents of the card plugged into the PI onto another one. The only thing you need is an USB SD Card writer. You cn accept the defaults when the cards are plugged in which allow you to copy the Internal SD Card onto the other one. Just be carefull that you do not overwrite your internal one. This feature can also be used to create backups of images that you have worked on and want to preserve.

Thus as you can see there is not much you need to do to prepare a PI to be used for burning the SD Card.

TODO: Python3

a) Card Burning from commandline:

- Insert card and find mmcblk0, e.g. no letter p in it for partition

```
sudo ls -ltr /dev/*
```

```
sudo dd bs=1M if=~/.cloudmesh/images/imagename.img
of=mmcblk0 status=progress conv=fsync
```

2) OSX:

a) Card Burning:

On OSX a good program is to use etcher for burning the images on disk:

- https://etcher.io/

To access it form the commandline you can also use

- https://etcher.io/cli/

b) File System Management:

Unfortunately, the free versions of writing the ext file system are no longer supported on OSX. This means that as of writing of this document the best solution we found is to purchase and install extFS on the MacOS computer you use for burning the SD Cards. If you find an alternative, please let us know. (We tested ext4fuse, which unfortunately only supports read access, see Appendix)

To easily read and write ext file systems, please install extFS which can be downloaded from

- https://www.paragon-software.com/home/extfs-mac/

The purchase price of the software is $39.95.

If you like to not spend any money we recommend that you conduct the burning on a raspberry pi.

TODO: PYTHON3 use pyenv

Tip: An alternative would be using virtualbox and using a virtual machine to avoid purchasing extFS.

C. Windows

a) Elevate permissions for Python.exe in Windows:

- Create a shortcut for python.exe
- Change the shortcut target into something like `C:\\xxx\\...\\python.exe`
- Click "advance..." in the property panel of the shortcut, and click the option "run as administrator"

b) Executable needed to burn the image on SD Card::

Download CommandLineDiskImager from the following url

- https://github.com/davidferguson/CommandLineDiskImager

The above executable will be used by cm-burn script.

It's necessary to burn the raspbian image to the SD card with this executable manually or thru Etcher in order to continue with next step.

```
CommandLineDiskImager.exe
C:\Users\John\Downloads\raspbian.img G
```

c) File System Management:

Download the Open source ext3/4 file system driver for Windows installer from

- http://www.ext2fsd.com/
- Open Ext2fsd exe
- The burned image in the previous step in SD card will have 2 partition
- FAT32 partition will be assigned with the Drive letter - Boot Drive
- Assign Drive Letter for EXT4 (Right click on the EXT4, Assign letter.
  The drive letter will be used while running cm-burn) - Root Drive
- Setting Automount of this EXT4
- F3 or Tools->Ext2 Volume Management
- Check-> Automatically mount via Ext2Mgr
- The instructions above needed for the Ext2fsd to reserve the Drive Letters and any raspbian image burned to SD will be auto mounted to the specific reserved drive letters. These drive letters need to be specified while using cm-burn

D. Installation

1) Install on your OS: Once you have decided which Computer system (MacOS, Linux, or Windows) you like to use for using the cm-burn program you need to install it. The program is written in python3 which we assume you have installed and is your default python in your terminal.

To install cm-burn, please execute

```
git clone https://github.com/cloudmesh/cm-burn.git
cd cm-burn
pip install .
```

In future it will also be hosted on pypi and you will be able to install it with

```
pip install git+https://github.com/cloudmesh/cm-burn
```

To check if the program works please issue the command

```
cm-burn check install
```

It will check if you have installed all prerequisites and are able to run the command as on some OSes you must be in the sudo list to runi it and access the SD card burner as well as mounting some file systems.

2) Usage:

a) cmburn.yaml:

```
cloudmesh:
    burn:
       image: None
```

b) Manual page:

1. git clone https://github.com/cloudmesh/cm-burn
2. cd cm-burn
3. python setup.py install
4. Copy the Raspberyy PI images to be burned under ~/.cloudmesh/images

The manual page is as follows:

```
cm-burn -h
Cloudmesh Raspberry Pi Mass Image Burner.

Usage:
  cm-burn create --group GROUP --names HOSTS --image IMAGE [--key=KEY]  [--ips=IPS]
  cm-burn gregor --group GROUP --names HOSTS --image IMAGE [--key=KEY]  [--ips=IPS]
  cm-burn ls
  cm-burn rm IMAGE
  cm-burn get [URL]
  cm-burn update
  cm-burn check install
  cm-burn (-h | --help)
  cm-burn --version

Options:
  -h --help     Show this screen.
  --version     Show version.
  --key=KEY     the path of the public key [default: ~/.ssh/id_rsa.pub].
  --ips=IPS     th ips in hostlist format
Location of the images to be stored for reuse:

  ~/.cloudmesh/images
  ~/.cloudmesh/inventory


Description:
  cm-burn create [--image=IMAGE] [--group=GROUP] [--names=
                 [--ips=IPS] [--key=PUBLICKEY] [--ssid=SSI
                 [--domain=DOMAIN]
                 [--bootdrive=BOOTDRIVE] [--rootdrive=ROOT
                 [-n --dry-run] [-i --interactive]
  cm-burn ls [-ni]
  cm-burn rm IMAGE [-ni]
  cm-burn get [URL]
  cm-burn update
  cm-burn check install
  cm-burn hostname [HOSTNAME] [-ni]
  cm-burn ssh [PUBLICKEY] [-ni]
  cm-burn ip IPADDRESS [--domain=DOMAIN] [-ni]
  cm-burn wifi SSID [PASSWD] [-ni]
  cm-burn info [-ni]
  cm-burn image [--image=IMAGE] [--device=DEVICE]
                [-ni]
  cm-burn (-h | --help)
  cm-burn --version

Options:
  -h --help         Show this screen.
  -n --dry-run      Show output of commands but don't exec
  -i --interactive  Confirm each change before doing it
  --version         Show version.
  --key=KEY         the path of the public key [default: ~
  --ips=IPS         the IPs in hostlist format
  --image=IMAGE     the image to be burned [default: 2018-

Example:
  cm-burn create --names red[000-010] ips --image rasbian_
  cmb-urn create --group g1 --names red[001-003] --key c:/
```

E. Appendix

1) OSX ext4fuse: Unfortunately ext4fuse only supports read access. To install it please use the following steps. However it will not allow you to use the cm-burn program. It may be useful for inspection of SD Cards

On OSX you will need brew and install osxfuse and ext4fuse

```
brew cask install osxfuse
brew install ext4fuse
```

To run it, your account must be in the sudoers list. Than you can do the following

```
mkdir linux
mkdir ssh
cp  ../*.img 00.img
```

```
brew cask install osxfuse
brew install ext4fuse
hdiutil mount 00.img
```

This will return

```
/dev/disk3              FDisk_partition_scheme
/dev/disk3s1            Windows_FAT_32
/dev/disk3s2            Linux
```

We can now access the boot partition with

```
ls /Volumes/boot/
```

This partition is writable as it is not in ext format.

However to access the Linux partition in read only form we need to mount it with fuse

```
sudo mkdir /Volumes/Linux
sudo ext4fuse /dev/disk2s2 /Volumes/Linux -o allow_other
ext4fuse /dev/disk2s2 linux
less linux/etc/hosts
sudo umount /Volumes/Linux
```

2) Activate SSH: see method 3 in https://www.raspberrypi.org/documentation/remote-access/ssh/

Draft:

Set up ssh key on windows (use and document the ubuntu on windows thing)

you will have ~/.ssh/id_rsa.pub and ~/.ssh/id_rsa

copy the content of the file ~/.ssh/id_rsa.pub into ???/.ssh/authorized_keys ??? is the location of the admin user i think the username is pi

enable ssh on the other partition while creating the fike to activate ssh

3) Hostname: change /etc/hostname

4) Activate Network: see https://www.raspberrypi.org/learning/networking-lessons/rpi-static-ip-address/

5) Change default password: From the net (wrong method):

Mount the SD card, go into the file system, and edit /etc/passwd. Find the line starting with "pi" that begins like this:

```
pi:x:1000:1000...
```

Get rid of the x; leave the colons on either side. This will eliminate the need for a password.

You probably then want to create a new password by using the passwd command after you log in.

The right thing to do is to create a new hash and store it in place of x. not yet sure how that can be done a previous student from the class may have been aboe to do that Bertholt is firstname.

could this work? https://unix.stackexchange.com/questions/81240/manually-generate-password-for-etc-shadow

```
python3 -c "from getpass import getpass; from
crypt import *; p=getpass(); print('\n'+crypt(p,
METHOD_SHA512)) if p==getpass('Please repeat: ')
else print('\nFailed repeating.')"
```

F. Unmount Drives on Windows

RemoveDrive.exe needs to be downloaded to `c:\Tools` from the following path and to have the Administrator rights (Right Click on the exe -> Properties -> Compatibility Tab -> Run this program as an Administrator

- https://www.uwe-sieber.de/drivetools_e.html

See also

- https://docs.microsoft.com/en-us/powershell/module/microsoft.powershell.management/remove-psdrive?view=powershell-6

Gregor thinks that unmounting is much easier in an aelevated command prompt using

```
mountvol <Drive Letter>: /d
```

VII. Links

- https://github.com/cloudmesh-community/hid-sp18-419/blob/master/cluster/headless_setup.md
- https://medium.com/@viveks3th/how-to-bootstrap-a-headless-raspberry-pi-with-a-mac-6eba3be20
  - network setup is not good as it requires additional step, we want to preconfigure on sd card and plug in multiple pis at once not a single one.
- https://github.com/cloudmesh/cloudmesh.pi/blob/dev/bin/cm-burn
- http://www.microhowto.info/howto/mount_a_partition_located
- http://www.janosgyerik.com/mounting-a-raspberry-pi-image-on-osx/
- https://github.com/Hitabis/pibakery
- http://osxdaily.com/2014/03/20/mount-ext-linux-file-system-mac/
- https://linuxconfig.org/how-to-mount-rasberry-pi-filesystem-image
- https://www.jeffgeerling.com/blogs/jeff-geerling/mounting-raspberry-pis-ext4-sd
- https://blog.hypriot.com/post/cloud-init-cloud-on-hypriot-x64/
- https://www.paragon-software.com/home/extfs-mac/

VIII. OSX during burning

```
/dev/disk0 (internal):
   #:                       TYPE NAME                    S
   0:      GUID_partition_scheme                         2
   1:                        EFI EFI                      3
```

```
   2:                 Apple_APFS Container disk1         2.0 TB     disk0s2

/dev/disk1 (synthesized):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      APFS Container Scheme -                      +2.0 TB     disk1
                                 Physical Store disk0s2
   1:                APFS Volume Macintosh HD            811.4 GB   disk1s1
   2:                APFS Volume Preboot                 26.8 MB    disk1s2
   3:                APFS Volume Recovery                519.0 MB   disk1s3
   4:                APFS Volume VM                      9.7 GB     disk1s4

/dev/disk2 (external, physical):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:     FDisk_partition_scheme                        *31.9 GB    disk2

/dev/disk3 (external, physical):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:     FDisk_partition_scheme                        *31.9 GB    disk3
```

Experiment DIY multiSDCard writer

We intend to experiment to build a multiSD card writer via USB. We will attempt to do this for OSX initially, therefore we like to order the following product

- USB Hub 3.0 Splitter, LYFNLOVE 7 Port USB Data

We will use multiple USB card readers (possibly just USB2 till we replacethem with USB3)

Than we will rewrite our program to attempt using the SDcard writers

```
Cloudmesh Raspberry Pi Mass Image Burner.
Usage:
  cm-burn create [--image=IMAGE]
                 [--group=GROUP]
                 [--names=HOSTS]
                 [--ips=IPS]
                 [--key=PUBLICKEY]
                 [--ssid=SSID]
                 [--psk=PSK]
                 [--domain=DOMAIN]
                 [--bootdrive=BOOTDRIVE]
                 [--rootdrive=ROOTDRIVE]
                 [-n --dry-run]
                 [-i --interactive]
  cm-burn ls [-ni]
  cm-burn rm IMAGE [-ni]
  cm-burn get [URL]
  cm-burn update
  cm-burn check install
  cm-burn hostname [HOSTNAME] [-ni]
  cm-burn ssh [PUBLICKEY] [-ni]
  cm-burn ip IPADDRESS [--domain=DOMAIN] [-ni]
  cm-burn wifi SSID [PASSWD] [-ni]
  cm-burn info [-ni]
  cm-burn image [--image=IMAGE]
                [--device=DEVICE]
                [-ni]
  cm-burn (-h | --help)
  cm-burn --version

Options:
  -h --help         Show this screen.
  -n --dry-run      Show output of commands but don't execute them
  -i --interactive  Confirm each change before doing it
  --version         Show version.
  --key=KEY         the path of the public key [default: ~/.ssh/id_rsa.pub].
  --ips=IPS         the IPs in hostlist format
  --image=IMAGE     the image [default: 2019-09-26-raspbian-buster.img]


Previously [default: 2018-06-27-raspbian-stretch.img]
Other images can be found at

https://downloads.raspberrypi.org/raspbian/images/

Files:
  This is not fully thought through and needs to be documented
  ~/.cloudmesh/images
  ~/.cloudmesh/inventory
  Location where the images will be stored for reuse

BUG:
  bootdrive and rootdrive will be removed in a future release as they are self
  discoverable

Description:
  cm-burn
  cm-burn create [--image=IMAGE]
                 [--group=GROUP]
                 [--names=HOSTS]
                 [--ips=IPS]
                 [--key=PUBLICKEY]
                 [--ssid=SSID]
                 [--psk=PSK]
                 [--bootdrive=BOOTDRIVE]
                 [--rootdrive=ROOTDRIVE]
  cm-burn update
        updates the downloaded images if new once are ava
  cm-burn ls
        lists the downloaded images
  cm-burn rm IMAGE
        remove the image
  cm-burn get URL
        downloads the image at the given URL
  cm-burn get jessie
        abbreviation to download a specific version of an
        Identify what would be useful.
  cm-burn hostname HOSTNAME
        writes the HOSTNAME as hostname on the currently
  cm-burn hostname
        reads the hostname form the current SD card

Example:
  cm-burn create --group=red --names=red[5-6] --ip=192.168
```

References

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[2] UCI Machine Learning Repository, "Spambase Data Set." https://archive.ics.uci.edu/ml/datasets/spambase.

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