UNIVERSITY OF STAVANGER

TECHNICAL MANUAL

Raspberry Pi 4 Cluster

Students
Dan Erik RAMSNES
Erlend Moen AL-KASIM

Supervisor
Naeem KHADEMI

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Contents

Overview

TODO: briefly explain this section

1.1 The Raspberry Pi 4 Cluster

TODO: talk and show a picture of the physical testbed

Raspberry Pi 4 Specifications					
CPU	RAM	NICs	Storage	USB	OS
Broadcom BCM2711 Cortex-A72 (ARMv7-rev3) 64-bit SoC 1.5GHz, Quad-core	4GB LPDDR4-2400 SDRAM	Gigabit Ethernet Controller (part of CPU) Dual IEEE 802.11ac WiFi 5, Bluetooth 5.0, BLE	32GB Micro-SD	2 USB 3.0 ports 2 USB 2.0 ports	Raspbian Buster (Linux)

Table 1.1: The hardware specifications of Raspberry Pi 4.

1.2 Network Topology

TODO: talk and show a diagram of the network topology

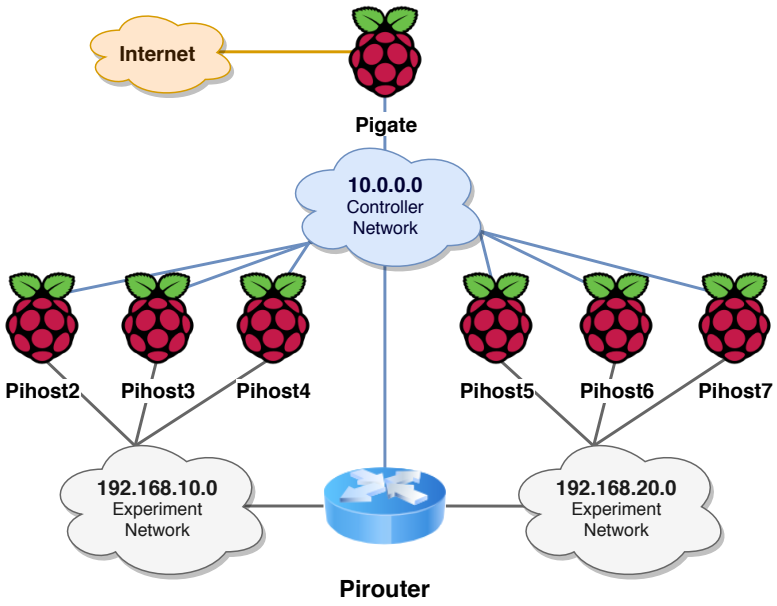

Figure 1.1: The logical network topology for the Raspberry Pi 4 cluster testbed. TODO: maybe update diagram to account for virtual interfaces and VLANs

Zyxel Switch

TODO: add zyxel model in title

TODO: briefly explain section content

2.1 VLAN Setup

TODO: show vlan setup

Gateway

TODO: briefly explain section content

3.1 Preliminaries

Before you begin, make sure the following have been done:

- Install an Operating System (OS) as specified in A.1.
- Change keyboard layout as specified in A.2.
- Create a root user account as specified in A.3.
- Update the system as specified in A.4.
- Enable SSH as specified in A.5.

The rest of the section will assume root access and that the OS from A.1 is used.

3.2 Network

The gateway is the only machine with direct Internet access through Dynamic Host Configuration Protocol (DHCP) on its main interface, with a virtual interface statically connected to the private controller network in order to communicate with the rest of the machines. To set up this, add the following to the /etc/network/interfaces file:

```
# Main interface (Internet access)
auto eth0
iface eth0 inet dhcp

# Subinterface (controller-network)
auto eth0:1
iface eth0:1 inet static
address 10.10.10.254
netmask 255.255.255.0
```

In order for the machines on the internal network to gain Internet access through the gateway, both IP forwarding and Network Address Translation (NAT) must be set up:

```
# Enable IP forwarding
echo 'net.ipv4.ip_forward=1' >> /etc/sysctl.conf

# NAT
update-alternatives --set iptables /usr/sbin/iptables-legacy
iptables -t nat -A POSTROUTING -o eth0 -j MASQUERADE
apt install iptables-persistent
```

Finally, change the hostname to pigate as specified in A.6 and reboot to apply all network changes.

TODO: ssh login without password

3.3 NTP Server

TEACUP requires that time is synchronized on all machines when running experiments. In order for the internal machines to synchronize their clock, an Network Time Protocol (NTP) server must be set up. The gateway will provide this service, and is set up as specified in A.7.

3.4 TEACUP

TEACUP requires a bunch of tools in order to function properly, as noted from the install guide. The following commands will install TEACUP properly:

```
# R
apt install -y r-base

# PDFJAM
apt install -y texlive-extra-utils

# SPP
apt install -y mercurial libpcap-dev build-essential
hg clone https://bitbucket.org/caia-swin/spp
cd spp
make
mkdir /usr/local/man/man1
make install
cd ..

# Fabric
apt install -y fabric python-pip python-dev libffi-dev libssl-dev
pip install fabric3
pip install -Iv pexpect==3.2

# TEACUP
wget https://sourceforge.net/projects/teacup/files/teacup-1.1.tar.gz
tar -xf teacup-1.1.tar.gz
```

To verify that TEACUP has been properly installed, a simple check can be done as follows:

```
mkdir experiment
cp teacup-1.1/example_configs/config-scenario1.py experiment/config.py
cp teacup-1.1/run.sh experiment/
cp teacup-1.1/fabfile.py experiment/
```

Go into the experiment folder and prepare to edit the config.py file. Find the line containing TPCONF_script_path = '/home/teacup/teacup-0.8' and change the path to where you extracted teacup-1.1. Finally, verify TEACUP installation with the command fab check_config. If no errors appear, all is good.

3.4.1 Modification

Due to the restricted physical set up as explained in 1.1 and 1.2, virtual interfaces have been used extensively. TODO: explain why tcpdump doesn't like this

A slight adjustment to TEACUP was therefore necessary.

TODO: show the teacup tcpdump unique name modification

TODO: completed experiments must be analysed on an x86 computer since the tool spp shits the bed on ARM

Router

TODO: briefly explain section content

4.1 Preliminaries

Before you begin, make sure the following have been done:

- Install an OS as specified in A.1.
- Change keyboard layout as specified in A.2.
- Create a root user account as specified in A.3.
- Update the system as specified in A.4.
- Enable SSH as specified in A.5.

The rest of the section will assume root access and that the OS from A.1 is used.

4.2 Network

The router serves as the intermediate device for the hosts in order to conduct more realistic experiments. The main interface is statically connected to the controller network, with additionally two virtual interfaces that function as the default gateway for the two separate subnets that the hosts reside in. To set the router up as such, add the following to the /etc/network/interfaces file:

```
# Main interface (controller-network)
auto eth0
iface eth0 inet static
address 10.0.0.1
netmask 255.255.255.0
gateway 10.0.0.254

# Subinterface for VLAN 10 (experiment-network)
auto eth0:10
iface eth0:10 inet static
address 192.168.10.1
netmask 255.255.255.0
gateway 10.0.0.254

# Subinterface for VLAN 20 (experiment-network)
auto eth0:20
iface eth0:20 inet static
address 192.168.20.1
netmask 255.255.255.0
gateway 10.0.0.254
```

In order for the hosts to communicate through the router, IP forwarding must be enabled:

```
# Enable IP forwarding
echo 'net.ipv4.ip_forward=1' >> /etc/sysctl.conf
```

Finally, change the hostname to pirouter as specified in A.6 and reboot to apply all network changes.

4.3 NTP Client

To synchronizate time for the router against the gateway, set the router up as an NTP client as specified in A.7.

4.4 TEACUP

The router only needs one tool for TEACUP to work properly when controlled from the gateway, and that is tcpdump:

```
# TEACUP tools on router
apt install -y tcpdump
```

Hosts

TODO: briefly explain section content

5.1 Preliminaries

Before you begin, make sure the following have been done:

- Install an OS as specified in A.1.
- Change keyboard layout as specified in A.2.
- Create a root user account as specified in A.3.
- Update the system as specified in A.4.
- Enable SSH as specified in A.5.

The rest of the section will assume root access and that the OS from A.1 is used.

5.2 Network

The hosts are separated into two subnets. Hosts 2, 3 and 4 are on the network 192.168.10.0/24 (VLAN10), while hosts 5, 6 and 7 are on 192.168.20.0/24 (VLAN20). The main interface on each host is statically connected to the controller network, with an additional virtual interface statically connected to the experimental network. To set up each host, add the following to the /etc/network/interfaces file, but replace yy with the appropriate virtual LAN (VLAN) and x with the correct host number as illustrated in 1.2:

```
# Main interface (controller-network)
auto eth0
iface eth0 inet static
address 10.0.0.x
netmask 255.255.255.0
gateway 10.0.0.254

# Subinterface (experiment-network)
auto eth0:yy
iface eth0:yy inet static
address 192.168.yy.x
netmask 255.255.255.0
gateway 192.168.yy.1
```

In order for the hosts to communicate between each subnet, a static route must be added. Create a file in /etc/network/**if**-up.d/ called simply route, and add the following:

```
#!/bin/sh
ip route add 192.168.yy.0/24 via 192.168.xx.1
```

Replace yy with the destination VLAN and xx with the source VLAN. For this script to be executed upon reboot, make it executable with the command chmod +x /etc/network/**if**−up.d/route.

Finally, change the hostname to pihostX as specified in A.6 but replace X with the correct host number, and then reboot to apply all network changes.

5.3 NTP Client

To synchronizate time for each host against the gateway, set up each host as an NTP client as specified in A.7.

5.4 Web10g

TODO: show how to compile web10g for Pi4

5.5 TEACUP

TODO: show all tools needed on the hosts for TEACUP to work properly

General

A.1 Installing an Operating System

To use the Raspberry Pi, an OS first needs to installed. Raspbian Buster Lite is the official OS for Raspberry Pi 4, and is used on every machine in the cluster.

After downloading the OS, uncompress the file. The extracted file should be of type .img, containing a preinstalled Raspbian Buster OS that now must be written to the SD card. To write the image file to the SD card, several tools exists that can be used, with some examples as follows:

- balenaEtcher (cross-platform)
- dd (Linux)

Once the image has been successfully written, simply put the SD card into the Raspberry Pi machine and boot it. The default user that comes preinstalled is called pi, with the default password raspberry.

A.2 Keyboard Layout

To change keyboard layout with a graphical user guide, simply run dpkg−reconfigure keyboard−configuration . For most full-sized keyboards, the following options are what you want; Generic 105−key PC (intl.) −> Norwegian −> Norwegian −> The **default for** the keyboard layout −> No compose key.

A.3 Root Account

Once logged in with user pi, create a root user with sudo passwd root. Enter a chosen password. A root user has now been created. To use it, log out with logout or simply reboot, and then log in as root.

To delete the pi user, issue the command deluser −−remove−home pi while logged in as root.

A.4 Updating the System

Note: *If the current system is using a custom kernel, upgrading the system will also upgrade the kernel, thus overwriting the custom kernel. One can omit the upgrade part if that is not desired.*

To update the system, run apt update && apt upgrade. If an error about release file not valid yet appears, the system's clock needs to be fixed. This can easily be done with the date tool; date −s "15 Feb 2020 12:00".

A.5 Enable SSH

To enable SSH access, simply run systemctl enable ssh. To allow SSH root login, the line PermitRootLogin yes must be added to the file /etc/ssh/sshd_config, which can conveniently be done with echo 'PermitRootLogin yes' >> /etc/ssh/sshd_config. Then start SSH service with systemctl start ssh or just reboot.

A.6 Change Hostname

There are two files that needs to be edited in order to change hostname. First, the /etc/hostname file, which only contains the current hostname. Simply change whatever is in it to what you want, say new_hostname . Second, the file /etc/hosts needs one line changed. Edit the line containg 127.0.1.1 so that it looks as follows:

```
127.0.1.1       new_hostname
```

Reboot to apply the changes.

A.7 Time Synchronization

First, set up a common timezone on all machines with timedatectl set−timezone CET.

NTP Server

Install ntp with apt install ntp. Then check if any NTP peers are connected with ntpq −p. If not, consider replacing the default pools or servers in /etc/ntp.conf with another, such as server ntp.uio.no followed up by systemctl restart ntp.

NTP Client

To automatically query for time from the NTP server, the Raspbian Buster OS already comes with a lightweight daemon called systemd−timesyncd that allows for synchronizing the system clock across the network. To specify which server to get the time from, prepare to edit the /etc/systemd/timesyncd.conf file. Uncomment the #NTP= line, and add 10.0.0.254 to it, which is the gateway.

Next, to enable and start the daemon, simply run timedatectl set−ntp true. Finally, either wait a bit or simply reboot, and verify time synchronization with either timedatectl timesync−status or date.

Terms

Dynamic Host Configuration Protocol (DHCP) A client/server protocol that automatically provides an Internet Protocol (IP) host with its IP address and other related configuration information such as the subnet mask and default gateway.

Network Address Translation (NAT) A method of remapping one IP address space into another. Often used such that one Internet-routable IP address of a NAT gateway can be used for an entire private network. This is used in conjunction with IP masquerading, which is a technique that hides an entire IP address space, usually consisting of private IP addresses, behind a single IP address in another, usually public address space.

Network Time Protocol (NTP) A networking protocol for clock synchronization between computer systems.

Operating System (OS) System software that manages computer hardware, software resources, and provides common services for computer programs.

Virtual LAN (VLAN) Any broadcast domain that is partitioned and isolated in a computer network at the data link layer (OSI layer 2).