Calcolo Parallelo dall'Infrastruttura alla Matematica

Calcolo parallelo: perché, quali infrastratture, quali problemi?

Laurea Triennale e Magistrale in Matematica

Fabio Durastante

April 28, 2023

Dipartimento
di Matematica
Università di Pisa

Table of Contents

Clusters

1 Building our machine

Cluster

"Clusters are an ensemble of **off-the-shelf computers** integrated by an **interconnection network** and operating within a single administrative domain and usually within a single machine room. Commodity clusters employ **commercially available networks** (e.g., **Ethernet**, Myrinet) as opposed to custom networks (e.g., IBM SP-2). *Beowulf-class* clusters incorporate mass-market PC technology for their compute nodes to achieve the best price/performance."

Beowulf Cluster Computing with Linux

Nodes and Network

1 Building our machine

A **node** is responsible for all activities and capabilities associated with executing an application program and supporting a sophisticated software environment:

1. instruction execution;
2. high-speed temporary information storage;
3. high-capacity persistent information storage, and
4. **communication** with the external environment, including **other nodes**.

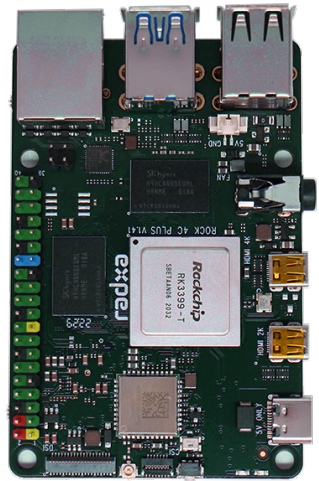
A **network** is a combination of *physical transport* and *control mechanisms* associated with a **layered hierarchy** of **message** encapsulation.

Building our machine

Let's start with **the nodes**:

Radxa ROCK 4C+

CPU	Arm® big.LITTLE™ technology: Dual Cortex® A72 frequency 1.5GHz and a Quad Cortex A53 frequency 1.0GHz,
GPU	Arm Mali™ T860MP4 GPU,
RAM	Dual channel 4GB 64bit LPDDR4,
LAN	1x Gigabit Ethernet port,
HD	1x micro SD card slot.



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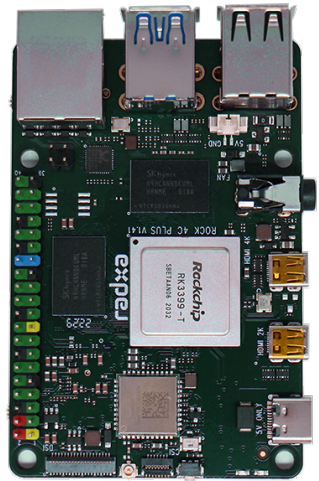
Why two processors?

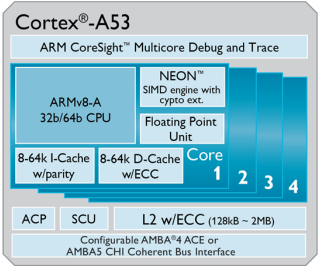


The ARM big.LITTLE architecture

The idea

ARM big.LITTLE is a **heterogeneous computing architecture** coupling *relatively* energy-saving and slower processor cores (LITTLE) with *relatively* more powerful and power-hungry ones (big).

- Only one ”side” or the other will be active at once,
- All cores have access to the same memory regions, so workloads can be swapped between *big* and *LITTLE* cores on the fly.



LITTLE

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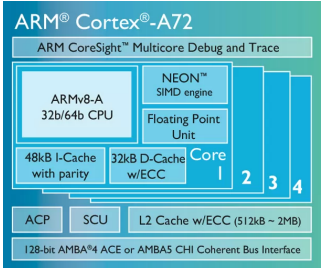


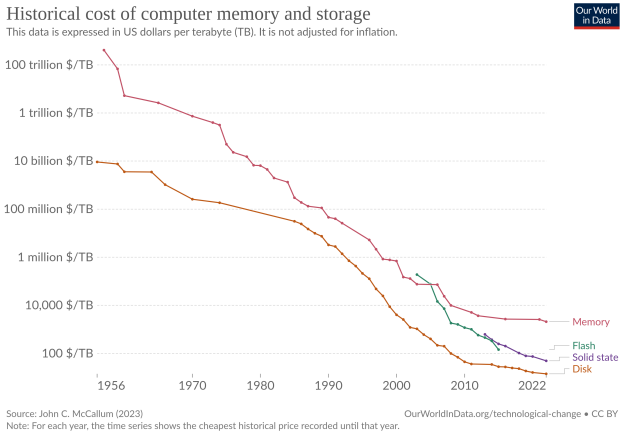
big

The 4GB 64bit LPDDR4 Memory

1 Building our machine

The LPDDR4 acronym stands for **L**ow-**P**ower **D**ouble **D**ata **R**ate **4** dynamic RAM.

Along with processor speed (*Moore's Law*), memory capacity has grown at a phenomenal rate, quadrupling in size approximately every three years.



HD: Storage

1 Building our machine

Each node will use Kingston 64 GB Micro SD (SDHC Class 10) SDCS/32GB with

- OS - Local to the node.
- Home - Where the users files and program will reside, it will be a *shared file system*.

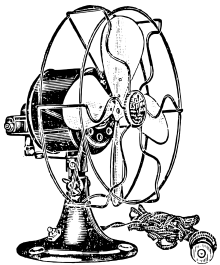
Power requirements and cooling

1 Building our machine

The Radxa ROCK 4C+ is **powered with a 5V source**.

- USB C 5V/3A,
- 5V Power applied to the GPIO PIN 2 & 4.

The recommended power source capacity is at least 5V/3A.



*"The Radxa ROCK 4C+ will operate perfectly well without any additional cooling and is **designed for sprint performance** - expecting a light use case on average then ramping up the CPU speed when needed (e.g. when loading a webpage). If a user wishes to load the system continually or operate it at a high termperature (sic.) at full performance, further cooling may be needed."*

OS: What flavor of Linux?

1 Building our machine

The Radxa ROCK 4C+ has **Debian/Ubuntu Linux support**, images can be obtained from:

https://wiki.radxa.com/Rockpi4/downloads

- Ubuntu 20.04.6 LTS (Focal Fossa),
- Server install image $\Rightarrow$ No GUI!
- Again, *why Linux*? Linux is the unchallenged champion for building compute engines with commodity parts: www.top500.org.

OS Setup

≈ 10 Gb for the OS:

- Compilers: GCC Suite v10.3.0,
- MPI: OpenMPI v4.0.3,
- OpenBLAS v0.3.8,
- Valgrind v3.15.0.

≈ 40 Gb of shared filesystem for the homes.

OS Setup

1 Building our machine

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All the **nodes** need to have the **same configuration** and **software**!

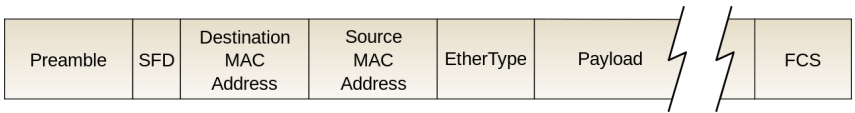
Table of Contents

2 Network architecture

The LAN Network

2 Network architecture

The Ethernet message packet comprises a sequence of **multibit fields**, one of which is variable length. The fields include a **combination** of **network control information** and **data payload**.



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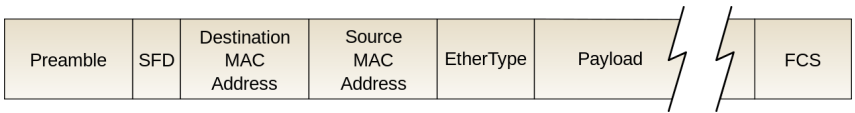


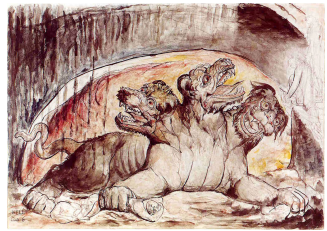
- TCP/IP is the *de facto* standard network communication protocol:
  - The **destination** of an Internet Protocol packet is specified by a 32-bit IP address, e.g., 192.168.1.2.
- Before assigning IP addresses to our nodes, designing the network topology, and booting all the machine, we need to **decide how the system will be accessed**: how a user can log in to a system and use the machine?

How do we access the system?

2 Network architecture

The Standalone System: unattached to any external networks, the user need to be in the same room of the machine.

The Universally Accessible Machine: every node is accessible from the entire Internet.



The Guarded Beowulf: reserved IPs to all internal nodes, and single front-end with an IP address accessible from outside.

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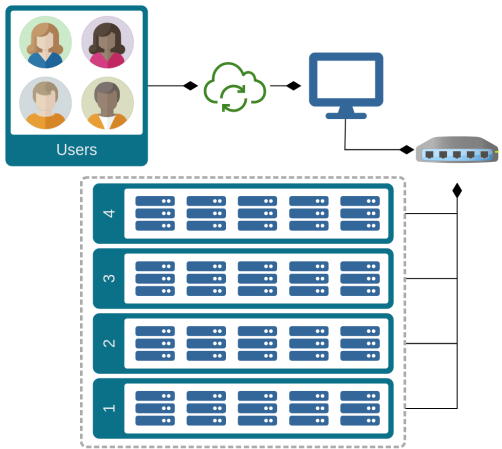
Our network architecture

2 Network architecture



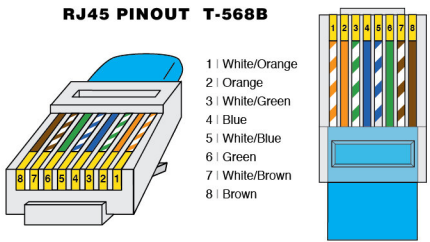
We will build a **guarded Beowulf** with an access node, where the user will log-in.

All the **nodes** will be connected to the **switch** via Ethernet connection, and will be powered through it.
The **access node** will be configured on the IP:

```
IP: 131.114.10.121
Gateway: 131.114.10.1
```

Ethernet Cables

2 Network architecture



1. Cut the cable to the length needed,
2. Strip back the cable jacket approximately 2.5 cm,
3. Use the **568-B wiring scheme** on both ends for a standard patch cable.

The **maximum length** for a cable segment is **100 meters**. If longer runs are required repeaters or switches are necessary.

Ethernet Cables

Pin	Pair	Wire	Color
1	2	1	
2	2	2	
3	3	1	
4	1	2	
5	1	1	
6	3	2	
7	4	1	
8	4	2	

ANSI/TIA-568 Standard

1. Cut the cable to the length needed,
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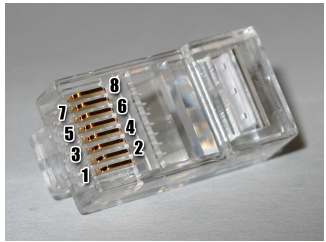
3. Use the **568-B wiring scheme** on both ends for a standard patch cable.



Power over Ethernet (PoE)

2 Network architecture

Power over Ethernet, or PoE, describes any of *several standards* or ad hoc systems that **pass electric power** *along* with **data** on **twisted-pair Ethernet cabling**.

- 24 10/100/1000Mbps RJ45 PoE+ Ports Switch with 2 SFP Slots,
- **PoE power budget** is up to **250 W** (in *laboratory environment*).

Compliant with IEEE802.3af/at
Isolation: 2.5kV
Power Input: DC44 57V
Power Output: DC5V 3A

Our “Rack”

2 Network architecture

- We will divide our 20 nodes into these racks,
- The fans must be connected on the red and black GPIOs (power and ground).

Table of Contents

Install the OS

3 Let's rock and roll

Since all the nodes have to be equal we move in **two steps**:

1. Install and configure the first node,
2. Make copies of the same SD for all the other nodes *or* execute same configuration commands everywhere.

Install the OS

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Since all the nodes have to be equal we move in **two steps**:

1. Install and configure the first node,
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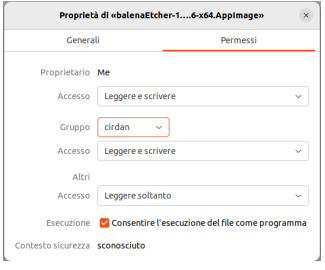
Let's start with **step 1**, we go to wiki.radxa.com/Rockpi4/downloads and download

- Etcher - A user friendly Image Writer,
- Ubuntu 20 Server(Linux 4.4).

We use Etcher to write the system image on the SD, on Linux this will be a `.appimage` file, so first of all we have to *make it executable*.

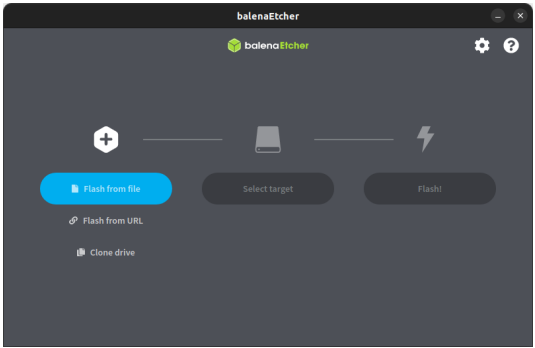
Remark: we need *root privileges*!



Install the OS

3 Let's rock and roll

Etcher is intuitive enough to use:



We select the Ubuntu 20 Server(Linux 4.4) image we have downloaded, then select the SD as target and the we flash the SD.

Gluster FS & Other Software

3 Let's rock and roll

To install GlusterFS in Ubuntu we could **follow these steps**:

```
apt install software-properties-common
add-apt-repository ppa:gluster/glusterfs-7
apt update
apt install glusterfs-server
```

Since we need to install the **same software** on **all** the **nodes**, we will use a default `#!/bin/bash` script to be run on each node with something like

```
for node in host1 host2; do
 scp /tmp/script.sh user@$node:/tmp/script.sh
 if [[ "$?" == "0" ]];then # checks that last command didn't fail
  ssh -oBatchMode=yes user@$node /tmp/script.sh
 fi
done
```

where `host?` is the name of the node and `user` the user that has to execute the code.

Initialization of the nodes

3 Let's rock and roll

The code should look something like:

```
#!/bin/bash
mkdir /scratch
chown -R rock:rock /home/rock
# Don't ask for anything
export DEBIAN_FRONTEND=noninteractive
# Cambia il fuso orario
timedatectl set-timezone Europe/London
# Fixa la chiave pubblica delle repository
# (da https://forum.radxa.com/t/gpg-error-with-ubuntu-server-20-04/1
↪  3392)
wget -O - apt.radxa.com/focal-stable/public.key | sudo apt-key add -
```

continue on the next slide

Initialization of the nodes

3 Let's rock and roll

continued from previous slide

```
# Update & Upgrade
apt update -y && apt upgrade -y
# Install required packages
apt -y install build-essential gcc openmpi-bin openmpi-common
↪  libopenmpi-dev slurm python3-pip valgrind tree git curl man-db
↪  mc parallel neovim unrar atool
```

This information is also available on the Wiki on the Git repository.

Work in Progress

3 Let's rock and roll

We still need to **configure**

- The `SLURM` queue manager,
- The *distributed* file-system GlusterFS.

The other important point is making the *accounts*!