*All machines are implement same version of ubuntu and having the same user account:*

**Step 1: Install ssh (ssh server and ssh client for all machines).**

* All machines: sudo apt-get update -> sudo apt-get upgrade
* Check ip addr ( all machines): sudo apt-get install net-tools -> ifconfig
* Install ssh server and client for all machines: sudo apt-get install openssh-server -> sudo apt-get install openssh-client.
* Create directory .ssh(for all machines): mkdir ~/.ssh -> chmod 700 ~/.ssh
* Genarate rsa key(all machines): ssh-keygen -t rsa -> enter the name of rsa file which inside directory .ssh -> enter the password of rsa file

+, master: /home/rodanus/.ssh/id\_rsa\_master

+, slave1: /home/rodanus/.ssh/id\_rsa\_slave1

* Copy id\_rsa\_xxx.pub file:

+, master: cat /home/rodanus/.ssh/id\_rsa\_slave1.pub >> /home/rodanus/.ssh/authorized\_keys

cat /home/rodanus/.ssh/id\_rsa\_slave2.pub >> /home/rodanus/.ssh/authorized\_keys

+, slave1: cat /home/rodanus/.ssh/id\_rsa\_master.pub >> /home/rodanus/.ssh/authorized\_keys

* Install getdit (for all machines): sudo apt-get install gedit
* Add 2 new line in file /etc/ssh/sshd\_config and restart ssh service for all machines:

sudo gedit /etc/ssh/sshd\_config -> then add 2 line: PubkeyAuthentication yes

RSAAuthentication yes

* Restart ssh service (all): sudo service ssh restart
* Runtest:

+, master (ip\_slave\_addr is noted when run ifconfig): ssh rodanus@<ip\_slave\_addr>

+, slave (ip\_master\_addr is noted when run ifconfig): ssh rodanus@<ip\_master\_addr>

Then enter rsa key

To logout run: exit

**Step 2: Install nfs**

On master:

* Install nfs server: sudo apt-get install nfs-kernel-server
* Create a directory: sudo mkdir -p /home/rodanus/Desktop/sharedfolder
* Change its permissions: sudo chown nobody:nogroup /home/rodanus/Desktop/sharedfolder
* sudo chmod 777 /home/rodanus/Desktop/sharedfolder
* install gedit: sudo apt-get install gedit -> sudo gedit /etc/exports
* add 2 line(slave1IP is ip noted before):

/home/rodanus/Desktop/sharedfolder <slave1IP>(rw,sync,no\_subtree\_check) /home/rodanus/Desktop/sharedfolder <slave2IP>(rw,sync,no\_subtree\_check)

Eg: /home/rodanus/Desktop/sharedfolder 192.168.4.36(rw,sync,no\_subtree\_check)

* export the shared directory: sudo exportfs -a
* restart nfs server: sudo systemctl restart nfs-kernel-server
* check firewall status (should be inactive): sudo ufw status

On slave:

* install nfs client: sudo apt-get install nfs-common
* create directory: sudo mkdir -p /home/rodanus/Desktop/sharedfolder
* mount sharedfolder (at slave side) to sharedfolder (at master side):

sudo mount <serverIP>:/home/rodanus/Desktop/sharedfolder /home/rodanus/Desktop/sharedfolder

Test nfs:

* On master: copy a file to sharedfolder -> the file will be seen at sharedfolder of each slave side!
* Note: if do not see the file, press ‘reload’.

**Step 3: Install OpenMPI in all machines**

* Install gcc for all machines: sudo apt-get install gcc
* sudo apt-get install openmpi-bin openmpi-common libopenmpi-dev libgtk2.0-dev
* download and decompress file openmpi for all machines. Go to open-mpi.org, download openmpi then copy it to home/rodanus/Desktop
* go to /home/rodanus/Desktop: cd home/rodanus/Desktop
* -> tar -xvf /home/rodanus/<the-file-name>
* Install openmpi for all machines: cd /home/rodanus/Desktop/openmpi-<version>
* -> ./configure –prefix=”home/rodanus/.openmpi” -> make -> sudo make install
* Export PATH:

export PATH=”$PATH:/home/rodanus/.openmpi/bin”

export LD\_LIBRARY\_PATH=”$LD\_LIBRARY\_PATH:/home/rodanus/.openmpi/lib”

* Test: run mpicc or mpirun

**Step 4: Run test**

* Edit file /etc/hosts for all machines:

+, on master: sudo gedit /etc/hosts ->comment all lines -> add lines

127.0.0.1 localhost

<slaveIP1> slave1….

+, onslave: sudo gedit /etc/hosts -> comment all lines-> add lines 127.0.0.1 localhost

<masterIP> master

* Compile mpi file:

+, on master: download example mpi from dropbox:

<https://www.dropbox.com/scl/fo/10icx7zax2631jyqfqf7t/AM4H-3IcGXsJ9VzWOGa7bdY?e=1&preview=mpi-prime.c&rlkey=nvggnucm1r0tjjzosx6oct81i&dl=0>

* mpicc <mpi\_file> -o ./outputfile -> copy outputfile to the sharedfolder

+, on slave: check if this file seen in shared folder

* run cluster:

+,master: go to sharedfolder then run: mpirun –hostfile /etc/hosts -np 5 ./outputfile

+, slave: run : top->then see the process named “outputfile”

**Example:**

<https://people.math.sc.edu/Burkardt/c_src/mpi/mpi.htm>

<https://github.com/GoroYeh56/Odd_Even_Sort---Parallel_Programming/blob/master/hw1.cc>