DISTRIBUTED SYSTEMS LABORATORY

SEMESTER – VI - CSE3261

CONTENTS

LAB – 1

PYTHON BASIC PRACTICE - I

1. Assigning Values to Variables

```
counter = 100 # An integer assignment
miles = 1000.0 # A floating point
name = "John" # A string
print (counter)
print (miles)
print (name)
```

2. Multiple Assignment

Python allows you to assign a single value to several variables simultaneously.

For example:

```
a = b = c = 1
a, b, c = 1, 2, "john"
```

Standard Data Types

Python has five standard data types:

□ Numbers

□ String

□ List

□ Tuple

□ Dictionary

Python Numbers

```
a = 5 # integer assignment
b= 4.56 #floating point assignment
#mathematical operations with scalar variables
```

print (5*a), would give the result 25

print (a/2) , would give the result 2.5

print(a**2), is the power (squaring operation) would give the result 25

import numpy as np

numpy includes various scientific functions like log 10, log2, natural log, exp, floor, ceil, rounding and all statistical summary functions.

Python Strings

```
str = 'Hello World!'
print (str) # Prints complete string
print (str[0]) # Prints first character of the string
print (str[2:5]) # Prints characters starting from 3rd to 5th
print (str[2:]) # Prints string starting from 3rd character
print (str * 2) # Prints string two times
print (str + "TEST") # Prints concatenated string
```

1. **Updating a string**

```
var1 = 'Hello World!'
print ("Updated String :", var1[:6] + 'Python')
```

Ans: Updated String :Hello Python

2. **String formatting operator**

One of Python's coolest features is the string format operator **%**. This operator is unique to strings and makes up for the pack of having functions f rom C's printf() family. Following is a simple example:

```
print( "My name is %s and weight is %d kg!" % ('Abay', 55))
```

My name is Abay and weight is 55 kg!

3. **Built–in String methods**

capitalize() , the first character of the string is converted to upper case.

```
str = "this is string example wow!!!";

print (str.capitalize())
```

Ans: This is string example   wow!!!

count(), counts the number of times a specific ‘substring’, occurrence in the main string

```
str = "this is string example...wow!!!";
```

```
str.count( ‘s’)
```

Ans: 3   # three times‘s’, appears in str.

find() , will locate the position of searching ‘substring’, (index)

```
Str.find(‘example’)
```

Ans: 15   #at 15th index, the substring ‘example’ is placed.

lower(),returns a copy of the string in which all case−based characters have been lowercased.

```
str = "THIS IS STRING EXAMPLE...WOW!!!";
print (str.lower())
```

this is string example... wow!!!

replace(), this method returns a copy of the string with all occurrences of substring old replaced by new.

```
str = "this is string example...wow!!! this is really string";
```

```
print (str.replace("is", "was"))
```

Ans: thwas was string example...wow!!! thwas was really string

swapcase(), this method returns a copy of the string in which all the case−based characters have had their case swapped.

```
str = "this is string example...wow!!!";
print (str.swapcase())
```

Ans: THIS IS STRING EXAMPLE... WOW!!!"

title(),returns a copy of the string in which first characters of all the words are capitalized.

```
str = "this is string example...wow!!!";
print (str.title())
```

Ans: This Is String Example...Wow!!!

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Python LIST

Lists are the most versatile of Python's compound data types. A list contains items separated by commas and enclosed within square brackets ([]). To some extent, lists are similar to arrays in C. One difference between them is that all the items belonging to a list can be of different data type.

The values stored in a list can be accessed using the slice operator ([ ] and [:]) with indexes starting at 0 in the beginning of the list and working their way to end −1. The plus (+) sign is the list concatenation operator, and the asterisk (*) is the repetition operator. For example:

```
list = [ 'abcd', 786 , 2.23, 'john', 70.2 ]
tinylist = [123, 'john']
print (list) # Prints complete list
print (list[0]) # Prints first element of the list
print (list[1:3]) # Prints elements starting from 2nd till 3rd
print (list[2:]) # Prints elements starting from 3rd element
print (tinylist * 2) # Prints list two times
print (list + tinylist) # Prints concatenated lists
```

Output will be like this

```
['abcd', 786, 2.23, 'john', 70.200000000000003]
abcd
[786, 2.23]
[2.23, 'john', 70.200000000000003]
[123, 'john', 123, 'john']

['abcd', 786, 2.23, 'john', 70.200000000000003, 123, 'john']
```

Note: LIST is mutable data type

Functions & Methods in LIST

```
list = ['physics', 'chemistry', 1997, 2000];

list.append(‘maths’)

Ans: ['physics', 'chemistry', 1997, 2000, ‘maths’];
```

To delete an element in a list

del list[2], will remove 1997 record from the list.

To check a data in a list,

‘physics’ in list, will return ‘True’

‘english’ in list, will return ‘False’

len(list), will return total items in list

list.count(‘physics’)

Ans: 1

list.pop (), will remove and return the last item from the list.

list = ['physics', 'chemistry', 1997, 2000];

list.pop()

Ans: ['physics', 'chemistry', 1997]

list.insert() , will insert an item in the specified index

list = ['physics', 'chemistry', 1997, 2000];

list.insert (2, ‘maths’)

Ans: ['physics', 'chemistry', ‘maths’, 1997, 2000];

list = ['physics', 'chemistry', 1997, 2000];

list.remove(‘chemistry’), will remove the item specified.

Ans: = ['physics', 1997, 2000];

list = ['physics', 'chemistry', 1997, 2000];

list.reverse(), will reverse the objects of the list in place.

Ans: [2000, 1997, ‘chemistry’,’physics’]

Python TUPLE

A tuple is another sequence data type that is similar to the list. A tuple consists of a number of values separated by commas. Unlike lists, however, tuples are enclosed within parentheses.

The main differences between lists and tuples are: Lists are enclosed in brackets ([ ]) and their elements and size can be changed, while tuples are enclosed in parentheses (( )) and cannot be updated. Tuples can be thought of as **read-only** lists.

```
tuple = ( 'abcd', 786 , 2.23, 'john', 70.2 )
list = [ 'abcd', 786 , 2.23, 'john', 70.2 ]
tuple[2] = 1000 # Invalid syntax with tuple
list[2] = 1000 # Valid syntax with list
```

Looping & Conditional Branches in Python

Eg.1

```
num=float(input(‘Enter a number:’))
if num>0:
   print(‘pos number’)
elif num==0:
   print(‘zero’)
else:
   print(‘Neg number’)
```

Eg.2

```
x=float(input(‘Enter a number:’))
if x<10:
   print(‘smaller’)
if x>20:
   print(‘bigger’)
print(‘Finished’)
```

Eg.3

```
x=5
print(‘Before 5’)
if x==5:
         print (‘this is 5’)
         print(‘still 5’)
print(‘After 5’)
print(‘Before 6’)
if x==6:
         print(‘this is 6’)
print (‘After 6’)
```

Eg.4: which will never print?

```
x=float(input(‘Enter a number:’))
if x<20:
    print(‘Below 20’)
elif x<10:
    print(‘Below 10’)
else:
    print(‘something else’)
```

Ans: Below 10

Eg.5: Nested Decisions

```
x=42
if x>1:
        print(‘above one’)
        if x<100:
                print(‘less than 100’)
print(‘All done’)
```

Eg.6: Ternary operator

```
age=15
b=(‘kid’ if age<18 else ‘adult’)
print(b)          #this will print ‘kid’
```

Usage of For-loop

Eg.1

```
for val in [5,4,3,2,1]:
        print(val)
 print (‘Done’)
```

Eg.2

```
stud=[‘Ram’,’Vijay’,’Nithya’,’Anu’,’Ramesh’,’suja’]
for k in stud:
        print(‘Hello:’, k)
print(‘done’)
```

Eg.3

```
for i in range(5):
    print(i)
    If i>2:
        print(‘Bigger than 2’)
    print(‘Done with i’,i)
```

Eg.4: Calculate factors of a number

```
x=int(input(‘Enter a number:’))
for  i  in  range(1,x+1):
     if x%i ==0:
        print(i)
x=10
1,2,5,10
```

Eg.5: Calculate largest number in an array

```
from math import *
Let x= [9, 41, 12, 3, 74, 15]
Largest=−inf
for i in x:
    if i>Largest:
        Largest=i
Print(Largest)
```

Eg.6: Calculate smallest number in an array

```
from math import *
Let x= [9, 41, 12, 3, 74, 15]
smallest=inf
for i  in  x:
    if i<smallest:
        smallest=i
print(smallest)
```

Eg.7: Calculate the count, sum and average of numerical array

```
Let x= [9, 41, 12, 3, 74, 15]

count=sum=avg=0

for  i  in  x:
    count=count+1
    sum=sum+1
avg=sum/count
print(count)
print(sum)
print(avg)
```

Eg.8: Filtering in a loop (print all numbers >20)

Let x= [9, 41, 12, 3, 74, 15]

```
for  i  in  x:
        if i>20:
                print (i)
```

Eg.9: For the above problem, instead of printing the result, store the elements in a variable (object)

Let x= [9, 41, 12, 3, 74, 15]

```
res=[]
for  i  in  x:
        if i>20:
                res.append(i)
```

Eg.10: For the above x, replace all elements <20 into zero. Store the result in different variable (object)

```
y=np.zeros(len(x))
for  i  in  range(len(x)):
        if x[i]>20:
                y[i]=x[i]
print(y)
```

Eg. 11: Program using elif to check more than one condition.

```
price = 100

if price > 100:
   print("price is greater than 100")
elif price == 100:
   print("price is 100")
elif price < 100:
   print("price is less than 100")
```

Eg. 12: Program using while loop -
program to display numbers from 1 to 5

```
 # initialize the variable
 i = 1
 n = 5

 # while loop from i = 1 to 5

 while i <= n:
 print(i)
  i = i + 1
```

Eg. 13:Take input from user , until user enters zero and calculate the sum of entered numbers.

```
total = 0
number = int(input('Enter a number: '))

# add numbers until number is zero

while number != 0:
total += number    # total = total + number

# take integer input again

number = int(input('Enter a number: '))
print('total =', total)
---------------------------------------------------   ---------------------------------------------------   --------
```

Lab Exercise Programs for Week 1

1. Write a program to find the area of rectangle. Take input from user.

   Eg. x= int(input('Enter number:'))
2. Write a program to swap the values of two variables.
3. Write a program to find whether a number is even or odd.
4. Write a program to check the largest among the given three numbers. (note: use elif here)
5. Write a program to demonstrate List functions and operations.
6. Consider the tuple(1,3,5,7,9,2,4,6,8,10). Write a program to print half its values in one line and the other half in the next line.
7. Consider the tuple (12, 7, 38, 56, 78). Write a program to print another tuple whose values are even number in the given tuple.
8. *Write a Python program to print nega*tive Numbers in a List using for loop. Eg. [11, −21, 0, 45, 66, −93].
9. Write a Python program to count positive and negative numbers in a List.
10. Write a Python program to remove all even elements from a list.

LAB – 2

PYTHON BASIC PRACTICE - II

Introduction to PANDAS

```
import pandas as pd

import numpy as np
```

PANDAS : Series data structure

```
s=pd.Series([3,9,−2,10,5])

s.sum()

25

s.min()

−2

s.max()

10
```

Creating a Data Frame

```
import pandas as pd

data = [['Dinesh',10],['Nithya',12],['Raji',13]]

df = pd.DataFrame(data,columns=['Name','Age'])

Name Age

0 Dinesh 10

1 Nithya 12

2 Raji 13
```

Indexed Data Frame

```
data = {'Name':['Kavitha', 'Sudha', 'Raju','Vignesh'],'Age':[28,34,29,42]}

df = pd.DataFrame(data, index=['rank1','rank2','rank3','rank4'])

Age  Name

rank1 28 Kavitha

rank2 34 Sudha

rank3 29 Raju

rank4 42 Vignesh
```

Creating a DataFrame using Dictionary

```
df1=pd.DataFrame({'A':pd.Timestamp('20130102'),'B':np.array([3]*4,dtype='int32'),
'C':pd.Categorical(['Male','Female','Male','Female'])})
```

```
A         B      C
0 2013-01-02 3 Male
1 2013-01-02 3 Female
2 2013-01-02 3 Male
3 2013-01-02 3 Female
```

```
df1.shape
(4,3)
```

```
df1.dtypes
A datetime64
B int32
C category
dtype: object
```

```
df1.head()
#will display first 5 records
```

```
df1.tail()
#will display last 5 records
```

```
df.summary()
```

```
           A          B          C          D
count 6.000000  6.000000   6.000000   6.000000
mean -0.175649  -0.208576  0.019053   -0.145193
std 1.286893    1.446490   0.678454   0.722313
min -2.567050   -1.968611  -0.782803  -0.962028
25% -0.345430   -1.435541  -0.472918  -0.609707
50% 0.174139    0.179390   -0.058210  -0.306675
75% 0.447666    0.557708   0.519626   0.230624
max 1.144652    1.648411   0.912454   1.005213
```

```
df.T     # will transpose the data frame
```

```
import pandas as pd
import numpy as np
```

```
dates=pd.date_range('20130101',  periods=100)
```

```
df = pd.DataFrame(np.random.randn(100,4), index=dates, columns=list('ABCD'))
```

To view first 5 records

```
>>> df.head()
```

To view last 5 records

```
>>> df.tail()
```

To view the index

```
>>> df.index
```

To view the column names

```
>>> df.columns
```

To transpose the df

```
>>> df.T
```

Sorting by Axis

```
>>> df.sort_index(axis=1, ascending=False)
```

Sorting by Values

```
>>> df.sort_values(by=’B’)
```

Slicing the rows

>>> df[0:3], which slice first 3 records (rows)

Slicing with index name

```
>>>  df[‘20130105’:’20130110’]
```

Slicing with row and column index (like 2D Matrix)

>>> df.iloc[0], will fetch entire 1st row

>>> df.iloc[0,:2], will fetch 1st row, first 2 columns

>>> df.iloc[0,0], will fetch 1st row, 1st column element (single element)

Selecting a single column

>>> df[‘A’], which yields a Series

Selecting more than one column

>>> df[[‘A’,’B’]], entire 2 columns

Selecting more than one column, with selected number of records
>>> df[[‘A’,’B’]][:5], first 5 records

[OR]

>>> df.loc[‘20130101’:’20130105’,[‘A’,’B’]][:5], first 5 records

Boolean Indexing

df[df.A>0], will fetch all positive values of A column

Include a 6th column (a categorical) character data

df[‘F’]=[‘Male’,’Female’,’Female’,’Male’,’Female’,’Female’]

Setting by assigning with a numpy array

df.loc[:,’D’]=np.array([5]*len(df))

Which will replace the ‘D’, column with all 5

Deleting a row or column

df.drop (‘col_name’, axis =1, inplace=True)

will drop the column name specified in col_name

df.drop (‘row_index’, axis =0, inplace=True)

will drop the row specified in row_index

Concatenation of two Data Frames

Let df1 be of size 10 x 5 and df2 of size 10 x 3 if concatenated horizontally (as a new column insertion)

Df_new= pd.concat (df1, df2, axis=1)
Df_new.shape
10 x 8

Let A dataframe of size 10 x 5 and B dataframe of size 15 x 5 if concatenated Vertically (as a new row insertion)

```
D= pd.concat (A, B, axis=0)
D.shape
```

25 x 5

** Sorting and Ordering a DataFrame:**

For the given DataFrame let us sort the age column

Let the dataframe be “A”

```
         Age     Name
rank1    28      Kavitha
rank2    34      Sudha
rank3    29      Raju
rank4    42      Vignesh
```

```
A.sort_values(by = ‘Age')
```

```
         Age     Name
rank1    28      Kavitha
rank3    29      Sudha
rank2    34      Raju
rank4    42      Vignesh
```

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I/O Operations with external files

# Reading a CSV file & XLS file format

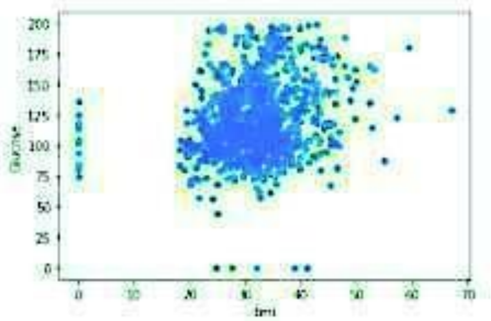
```
df = pd.read_csv(‘xyz.csv',header=None)
df.head() #This will display 1st 5 records
df.tail() #This will display last 5 records
```

The above dataset doesn’t have header, we shall attach our own header.

```
df.columns=['preg','glu','bp','sft','ins','bmi','dpf','age','class']
```

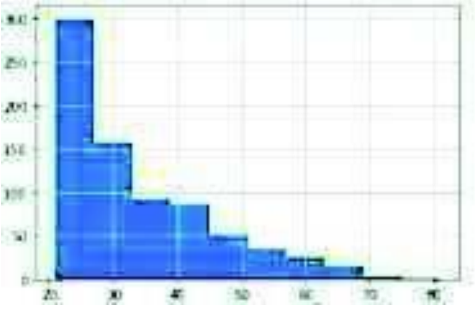
#Let us visualize the scatter plot of two continuous variable.

```
plt.scatter(df['bmi'],df['glu'])
plt.xlabel('bmi')
plt.ylabel('Glucose')
```

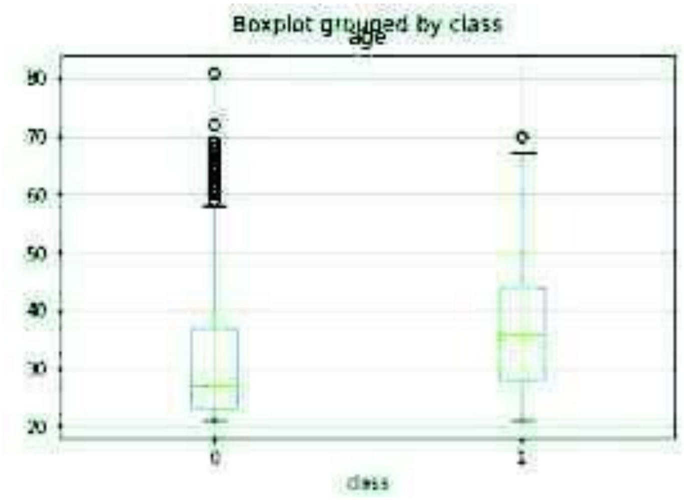


#Let us visualize the histogram of another continuous variable ‘Age’

```
df['age'].hist()
```



#Let us visualize the distribution ‘Age’ with respect to Categories: Label-O(Healthy), Label-1 (Diabetes)



#We can observe the median age of diabetes is slightly greater than median age of healthy

```
W = pd.read_csv('xyz.xls',header=None)
W.head() #XLS file format also, we can read using pd.read_csv
D= np.loadtxt('xyz.data',delimiter=",")
D[:5,:] # this file is loaded in Numpy 2D array format
```

# Reading a XLSX file format

```
G=pd.read_excel(xyz.xlsx',sheet_name='Sheet1')
G.head()
```

Here additionally we need to pass the sheet_name. If not specified, it will read the first page by default.

# Reading a HTML file format

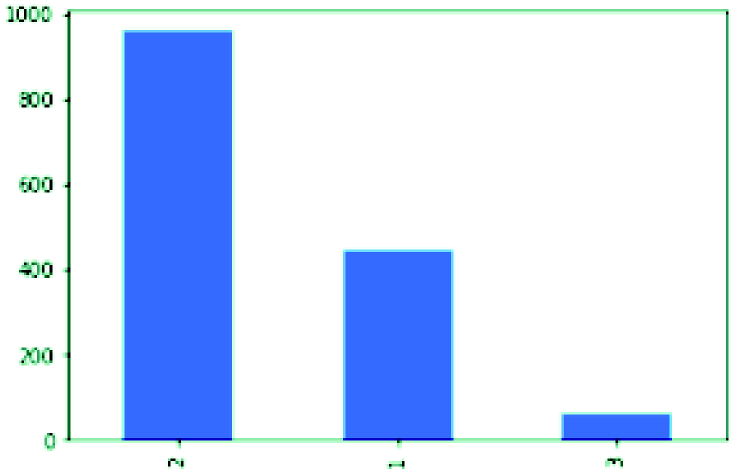
Pandas can read table tabs off of html. For example:

```
B = pd.read_html('http://www.fdic.gov/bank/individual/failed/b
anklist.html')
```

# Reading a TXT file format

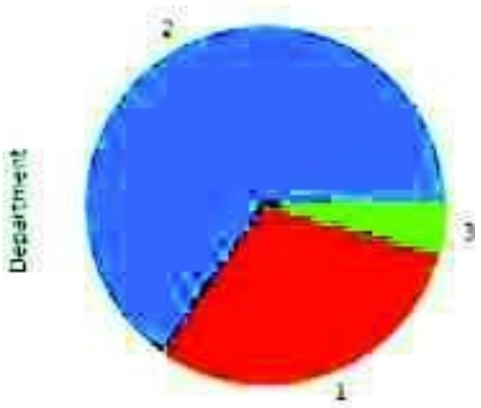
```
H = pd.read_table('HR.txt')
H.head()
f=H['Department'].value_counts()
f
2 961
1 446
3 63
```

```
#We can visualize the distribution of categorical values using
bar plot and pie chart
f.plot(kind='bar')
```

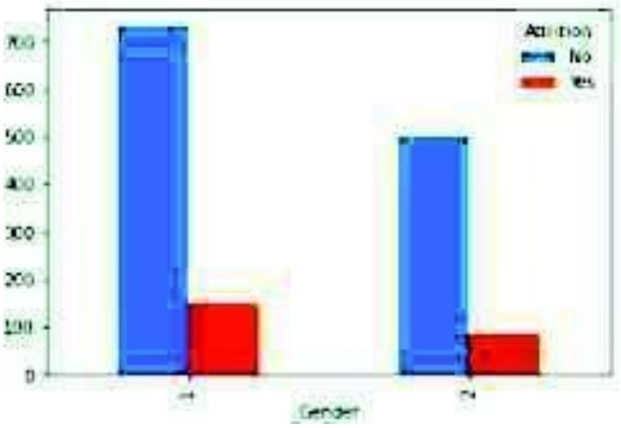


The above bar plot can be perceived in terms of Pie chart which would give % percentage information

```
f.plot(kind='pie')
```



```
#We can visualize two categorical variables at a time
fa=pd.crosstab(H['Gender'],H['Attrition'])
fa.plot(kind='bar')
```



Attrition
No
Yes
700
600
500
400
300
200
100
0
Gender

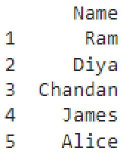
-- -- --------

Lab Exercise Programs for Week 2:

11. Write a program to demonstrate while loop with else.
12. Write a program to print negative Numbers in a List using while loop.
13. Define a dictionary containing Students data {Name, Height, Qualification}.
    a) Convert the dictionary into DataFrame
    b) Declare a list that is to be converted into a new column (Address}
    c) Using 'Address' as the column name and equate it to the list and display the result.
14. Define a dictionary containing Students data {Name, Height, Qualification}.
    a) Convert the dictionary into DataFrame
    b) Use DataFrame.insert() to add a column and display the result.
15. a) Create two data frames df1 and df2. df1 contains one column 'Name' and df2 contains 4 columns 'Maths', 'Physics', 'Chemistry' and 'Biology' .

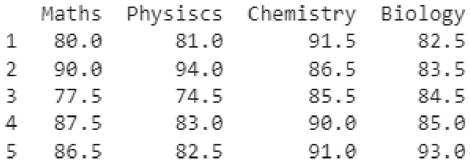
    b) Concatenate two data frames df1 and df2. Now insert one column 'Total' to the new data frame df_new and find the sum of all marks.

df1:



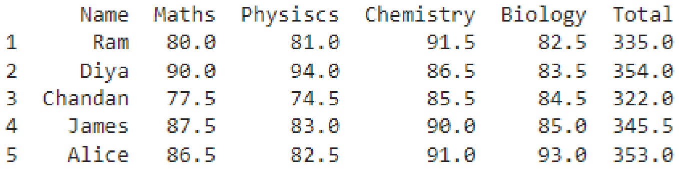
```
      Name
1      Ram
2     Diya
3  Chandan
4    James
5    Alice
```

df2:



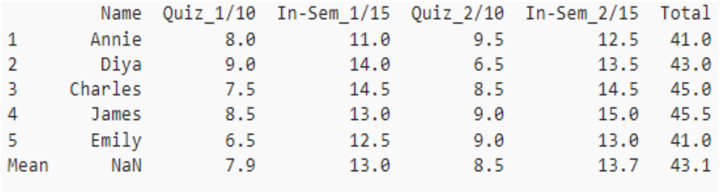
```
  Maths  Physiscs  Chemistry  Biology
1  80.0      81.0       91.5     82.5
2  90.0      94.0       86.5     83.5
3  77.5      74.5       85.5     84.5
4  87.5      83.0       90.0     85.0
5  86.5      82.5       91.0     93.0
```

df_new:



```
      Name  Maths  Physiscs  Chemistry  Biology  Total
1      Ram   80.0      81.0       91.5     82.5  335.0
2     Diya   90.0      94.0       86.5     83.5  354.0
3  Chandan   77.5      74.5       85.5     84.5  322.0
4    James   87.5      83.0       90.0     85.0  345.5
5    Alice   86.5      82.5       91.0     93.0  353.0
```

16. Create a data frame with column- **Name, Quiz_1 /10, In-Sem_1 /15, Quiz_2 /10 and In-Sem_2 /15**. Now insert a column **Total** and find the total and mean as given in the below table.



```
         Name  Quiz_1/10  In-Sem_1/15  Quiz_2/10  In-Sem_2/15  Total
1       Annie        8.0         11.0        9.5         12.5   41.0
2        Diya        9.0         14.0        6.5         13.5   43.0
3     Charles        7.5         14.5        8.5         14.5   45.0
4       James        8.5         13.0        9.0         15.0   45.5
5       Emily        6.5         12.5        9.0         13.0   41.0
Mean      NaN        7.9         13.0        8.5         13.7   43.1
```

LAB – 3

PYTHON BASIC PRACTICE - III

Usage of Numpy Data Structure

Import numpy as np

1. Array creation

A = np.array ([2,5,10])

A.dtype

Will show, int64 data type

B=np.array ([2.4,10.6,5.2])

B.dtype

Will show, float64 data type

Creating sequence of sequence will create 2-dimensional array.

A=np.array([(3,4,5),(12,6,1)])

Z=np.zeros((2,4)) # will create zero matrix of dimension 2x4

Similarly, np.ones((3,3)) # will create one's matrix of dimension 3x3

To create a sequence of data,

S=np.arange(10,30,5)

Print (S) will give (10,15,20,25,30), with step size of 5

np.arange(0, 2, 0.3) # it accepts float arguments

array([0. , 0.3, 0.6, 0.9, 1.2, 1.5, 1.8])

#Instead of step-size, we can specify total number of elements in the array using

S1=np.linspace(0,2,9) # produce 9 numbers starting 0 & ends with 2

```
array([ 0.  ,  0.25,  0.5 ,  0.75,  1.  ,  1.25,  1.5 ,  1.75,  2.  ])
```

#usage of Random Number functions

import random

random.choice([1,2,3,4,5]), this will pick one number from the list randomly

random.choice('python'), will pick one character from the string randomly

random.randrange(25,50), will pick one integer between 25 to 50

random.randrange(25,50,2), will pick one integer between 25 to 50 with step size of 2

random.random(), will pick a random number between 0 to 1

random.uniform(5,10), will pick a floating point number between 5 to 10

random.shuffle([1,2,3,4,5]), will shuffle the list elements

random.seed(10), to get same random value during every execution

2-Dimensional array (Matrix)

a = np.arange(15).reshape(3, 5)

```
array([[ 0,  1,  2,  3,  4],
      [ 5,  6,  7,  8,  9],
      [10, 11, 12, 13, 14]])
```

#to check the dimension

```
a.shape
(3,5)
a.size # will return total elements in matrix (here 15)
```

# to transpose a matrix

a.T # transposed to 5x3 matrix

3-Dimensional array

c = np.arange(24).reshape(2,3,4) # 1st value indicates (no of planes) (3,4) is the dimension

```
print(c)
[[[ 0  1  2  3]
  [ 4  5  6  7]
  [ 8  9 10 11]]
 [[12 13 14 15]
  [16 17 18 19]
  [20 21 22 23]]]
```

c.shape will return (2,3,4)
c[1,...] is equal to c[1,:,:] # will fetch all elements of 2nd plane
c[...,2] is equal to c[:,:,2] [[3,7,11],[15,19,23]]

Array operations

```
a = np.array( [20,30,40,50] )
b = np.arange( 4 )
b
array([0, 1, 2, 3])
c = a−b
c
array([20, 29, 38, 47])
b**2
array([0, 1, 4, 9])
10*np.sin(a)
array([ 9.12945251, −9.88031624, 7.4511316 , −2.62374854])
a<35
array([ True, True, False, False], dtype=bool)
```

Matrix operations

```
A = np.array( [[1,1],[0,1]] )
B = np.array( [[2,0],[3,4]] )
A*B                    # elementwise product
array([[2, 0],
      [0, 4]])
A.dot(B)                 # matrix product
array([[5, 4],
      [3, 4]])
```

(OR)

```
np.dot(A, B)               # another matrix product
array([[5, 4],
      [3, 4]])
```

```
b = np.arange(12).reshape(3,4)
b
array([[ 0,  1,  2,  3],
      [ 4,  5,  6,  7],
      [ 8,  9, 10, 11]])

b.sum(axis=0)                    # sum of each column
array([12, 15, 18, 21])

b.sum(axis=1)                    # sum of each row
array([6, 22, 38])
```

Indexing, Slicing & Iterating Array

```
a = np.arange(10)**3
a
array([  0,  1,   8,  27,  64, 125, 216, 343, 512, 729])

a[2:5]
array([ 8, 27, 64])

a[0:6:2]

array([0,8,64,216])
```

Let ‘**b**’, is an input matrix of size 5x4

```
array([[ 0,  1,  2,  3],
       [10, 11, 12, 13],
       [20, 21, 22, 23],
       [30, 31, 32, 33],
       [40, 41, 42, 43]])

b[2,3] #will fetch 23

b[0:5,1] or b[:5,1] or b[:,1] #will fetch [1,11,21,31,41]

b[−1,:] # will fetch last row
b[:,−1] # will fetch last col


for row in b:
   print (row)  # will print every row
```

```
for element in b.flat:
   print (element) # will show all elements of b in 1−D array
```

Changing the shape of a matrix

```
b.ravel() # returns the array flattened to (1x 20)
```

Later, we can convert 5x4 matrix into 4x 5 matrix using

```
B1=b.reshape(4,5)
```

Stacking together different arrays

```
A1=np.array([(3,4,5),(12,6,1)])
```

```
3   4  5
12  6  1
```

```
A2=np.array([(1,2,6),(−4,3,8)])
```

```
 1 2 6
−4  3  8
```

```
D1=np.vstack((A1,A2))
```

```
3   4  5
12  6  1
1   2  6
−4  3  8
```

```
D2=np.hstack((A1,A2))
```

```
3   4  5  1  2  6
12  6  1 −4  3  8
```

Stacking 1-D array into 2-D array (column wise)

```
a = np.array([4.,2.])
b = np.array([3.,8.])
```

```
np.column_stack((a,b))    # returns a 2D array
```

```
array([[ 4., 3.],
       [ 2., 8.]])
```

```
np.hstack((a,b))         # the result is different
array([ 4., 2., 3., 8.])

np.hstack((a[:,newaxis],b[:,newaxis])) # the result is the same
array([[ 4.,  3.],
      [ 2.,  8.]])
```

Indexing with array of indices

```
a = np.arange(12)**2                    # the first 12 square numbers
i = np.array( [ 1,1,3,8,5 ] )           # an array of indices
a[i]                                    # the elements of a at the positions i
array([ 1,  1,  9, 64, 25])

j = np.array( [ [ 3, 4], [ 9, 7 ] ] )      # a bidimensional array of indices
a[j]                              # the same shape as j

array([[ 9, 16],
      [81, 49]])
```

Usage of for-loop (Mapping by Value)

Calculate sum of all the elements in a 2D Numpy Array (iterate over elements)

```
import numpy as np
a=np.array([(3,2,9),(1,6,7)])

s1=0
for row in a:
    for col in row:
        s1+=col
print(s1)
```

Usage of for-loop (Mapping by Index)

Calculate sum of all the elements in a 2D Numpy Array (iterate over range)

```
import numpy as np
a=np.array([(3,2,9),(1,6,7)])
s=0
for i in range(a.shape[0]):
    for j in range(a.shape[1]):
        s+=a[i,j]
print(s)
```

-- -- --------

Lab Exercise Programs for Week -3:

1. Write a program to find the factors of a given number (get input from user) using for loop.
2. Find the sum of columns and rows using axis.
3. Operations on Arrays (use numpy wherever required):
    a) Create array from list with type float
    b) Create array from tuple
    c) Creating a 3X4 array with all zeros
    d) Create a sequence of integers from 0 to 20 with steps of 5
    e) Reshape 3X4 array to 2X2X3 array
    f) Find maximum and minimum element of array, Row wise max and min, column wise max and min and sum of elements. (Use functions max(), min(), sum())
4. Write a program to transpose a given matrix.
5. Write a program to add two matrices.
6. Write a program to find element wise product between two matrices.

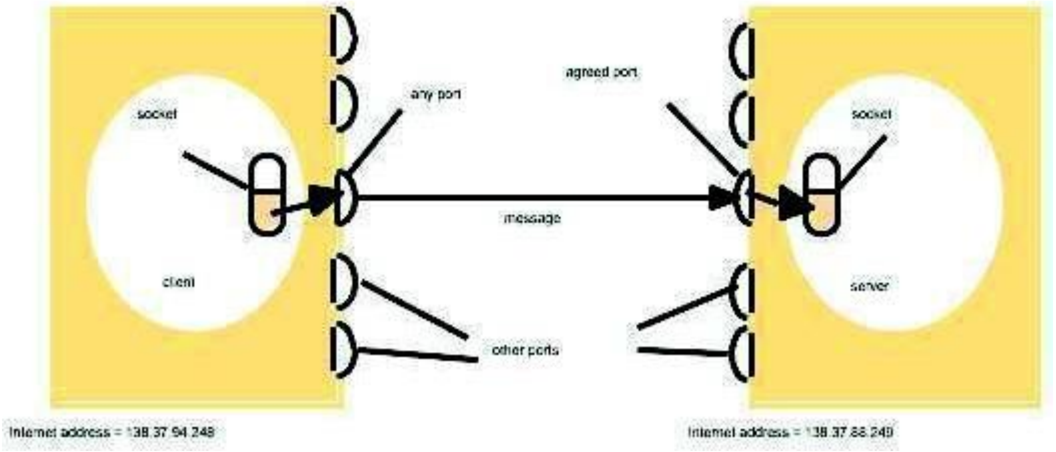
LAB – 4

SOCKET PROGRAMMING USING PYTHON

Socket Programming in Python

Socket Basics:

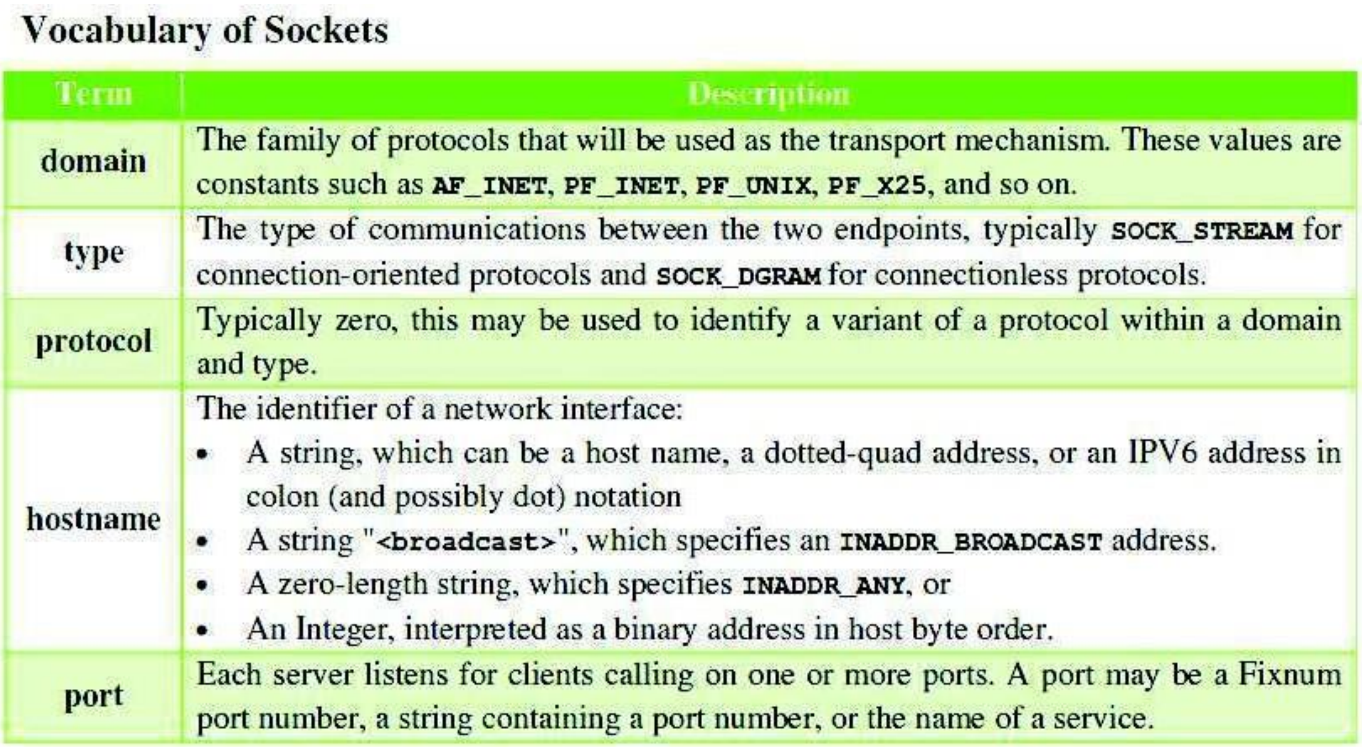
A *network socket* is an endpoint of an inter-process communication flow across a computer network. Sockets may communicate within a process, between processes on the same machine, or between processes on different continents. Today, most communication between computers is based on the internet protocol; therefore most network sockets are *internet sockets*. To create a connection between machines, Python programs import the **socket** module, create a socket object, and call the object's methods to establish connections and send and receive data. Sockets are the endpoints of a bidirectional communications channel.



agreed port
any port
socket
socket
message
client
server
other ports
Internet address = 138.37.94.248
Internet address = 138.37.88.249

Socket in Python:

Python provides two levels of access to network services. At a *low level*, you can access the basic socket support in the underlying operating system, which allows you to implement clients and servers for both connection-oriented and connectionless protocols. Python also has libraries that provide *higher level* access to specific application level network protocols, such as FTP, HTTP, SMTP, and soon. Sockets may be implemented over a number of different channel types: UNIX domain sockets, TCP, UDP, and so on. The socket library provides specific classes for handling the common transportsas well as a generic interface for handling the rest.



Vocabulary of Sockets

Term	Description
domain	The family of protocols that will be used as the transport mechanism. These values are constants such as **AF_INET**, **PF_INET**, **PF_UNIX**, **PF_X25**, and so on.
type	The type of communications between the two endpoints, typically **SOCK_STREAM** for connection-oriented protocols and **SOCK_DGRAM** for connectionless protocols.
protocol	Typically zero, this may be used to identify a variant of a protocol within a domain and type.
hostname	The identifier of a network interface: • A string, which can be a host name, a dotted-quad address, or an IPV6 address in colon (and possibly dot) notation • A string "**<broadcast>**", which specifies an **INADDR_BROADCAST** address. • A zero-length string, which specifies **INADDR_ANY**, or • An Integer, interpreted as a binary address in host byte order.
port	Each server listens for clients calling on one or more ports. A port may be a Fixnum port number, a string containing a port number, or the name of a service.

The *socket* Module:

To create a socket, you must use the ***socket.socket()*** **function** available in *socket* module, which has the general syntax:

```
s = socket.socket (socket_family, socket_type, protocol=0)
```

Here is the description of the parameters:

- **socket_family:** This is either AF_UNIX or AF_INET, as explained earlier.
- **socket_type:** This is either SOCK_STREAM or SOCK_DGRAM.
- **protocol:** This is usually left out, defaulting to 0.

Once you have *socket* object, then you can use required functions to create your client or server program.

Server Socket Methods

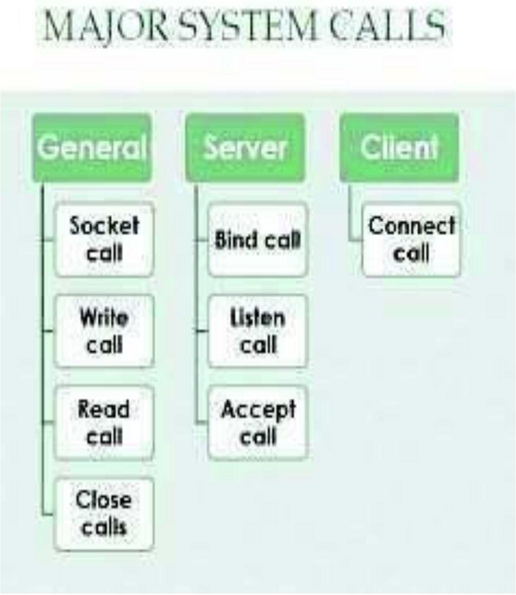
Method	Description
s.bind()	This method binds address (hostname, port number pair) to socket.
s.listen()	This method sets up and start TCP listener.
s.accept()	This passively accept TCP client connection, waiting until connection arrives (blocking).

Client Socket Methods

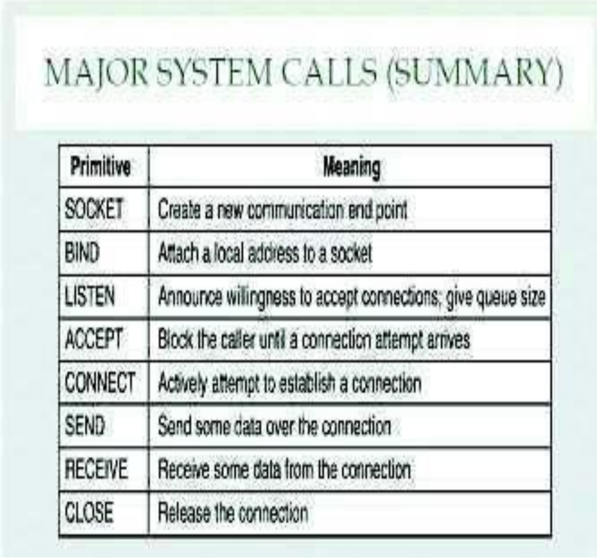
Method	Description
s.connect()	This method actively initiates TCP server connection.

General Socket Methods

Method	Description
s.recv()	This method receives TCP message
s.send()	This method transmits TCP message
s.recvfrom()	This method receives UDP message
s.sendto()	This method transmits UDP message
s.close()	This method closes socket
socket.gethostname()	Returns the hostname.

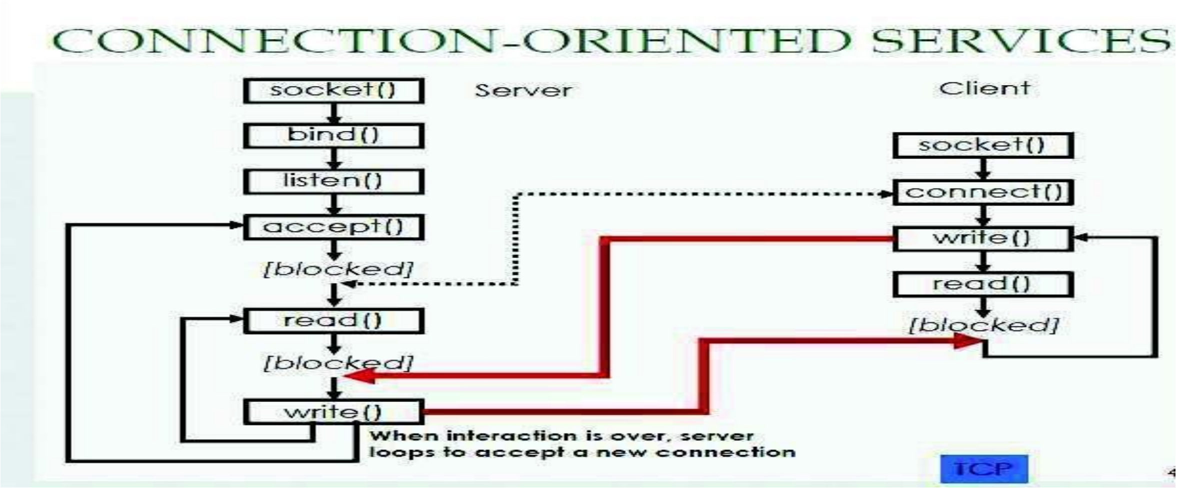


MAJOR SYSTEM CALLS



MAJOR SYSTEM CALLS (SUMMARY)

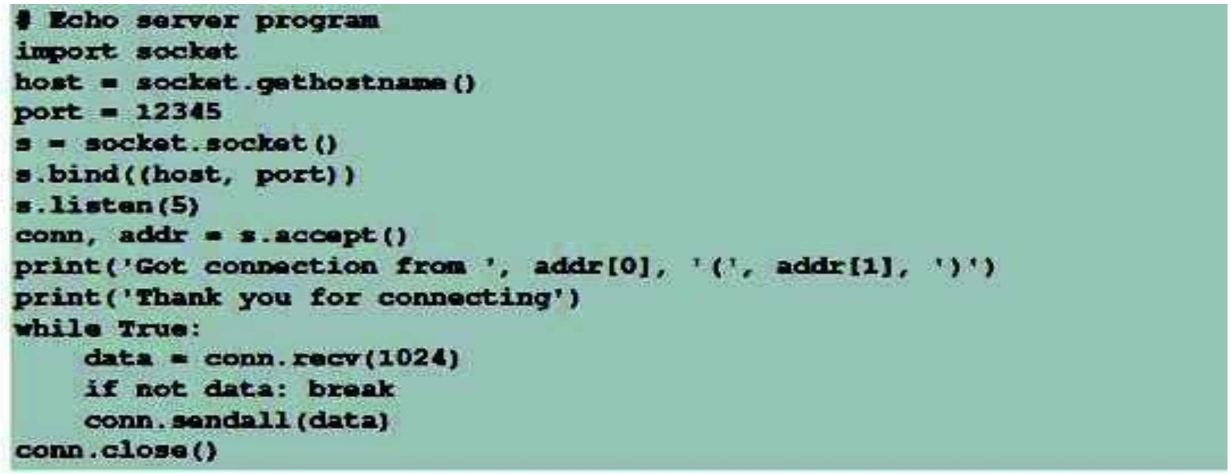
Primitive	Meaning
SOCKET	Create a new communication end point
BIND	Attach a local address to a socket
LISTEN	Announce willingness to accept connections; give queue size
ACCEPT	Block the caller until a connection attempt arrives
CONNECT	Actively attempt to establish a connection
SEND	Send some data over the connection
RECEIVE	Receive some data from the connection
CLOSE	Release the connection



A Simple Server:

To write Internet servers, we use the **socket** function available in socket module to create a socket object.

A socket object is then used to call other functions to setup a socket server. Now call **bind(hostname, port)** function to specify a *port* for your service on the given host. Next, call the *accept* method of the returned object. This method waits until a client connects to the port you specified, and then returns a *connection* object that represents the connection to that client.



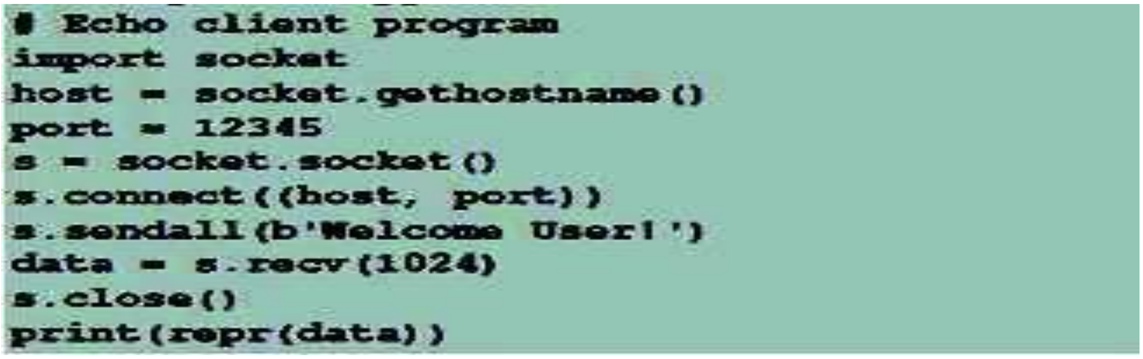
```
# Echo server program
import socket
host = socket.gethostname()
port = 12345
s = socket.socket()
s.bind((host, port))
s.listen(5)
conn, addr = s.accept()
print('Got connection from ', addr[0], '(', addr[1], ')')
print('Thank you for connecting')
while True:
    data = conn.recv(1024)
    if not data: break
    conn.sendall(data)
conn.close()
```

A Simple Client:

Now we will write a very simple client program which will open a connection to a given port 12345 and given host. This is very simple to create a socket client using Python's *socket* module function.

The **socket.connect(hosname, port)** opens a TCP connection to *hostname* on the *port*. Once you have a socket open, you can read from it like any IO object. When done, remember to close it, as you would close a file.

The following code is a very simple client that connects to a given host and port, reads any available data from the socket, and then exits:



```
# Echo client program
import socket
host = socket.gethostname()
port = 12345
s = socket.socket()
s.connect((host, port))
s.sendall(b'Welcome User!')
data = s.recv(1024)
s.close()
print(repr(data))
```

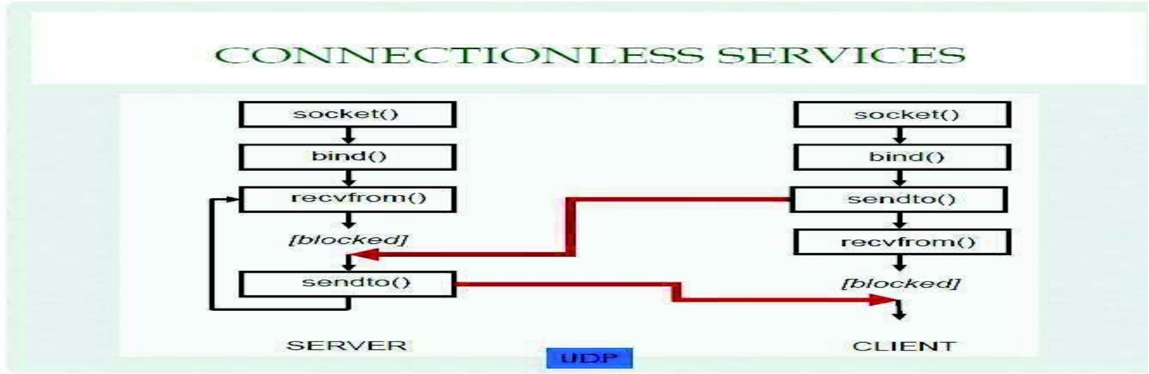
Note: The repr() function returns a printable representational string of the given object.

Now run this ***server.py*** in background and then run above ***client.py*** to see the result.

Output:

Step 1: Run ***server.py***. It would start a server in background.

Step 2: Run ***client.py***. Once server is started run client.



<u>Simple Connectionless Server</u>

import socket

```
sock = socket.socket(socket.AF_INET,socket.SOCK_DGRAM)      # For UDP

udp_host = socket.gethostname()                              # Host IP
udp_port = 12345                                          # specified port to connect

sock.bind((udp_host,  udp_port))

while True:
            print "Waiting for client..."
            data,addr = sock.recvfrom(1024)          #receive data from client
            print "Received Messages:",data.decode()," from",addr
```

Simple Connectionless Client:

```
import socket

sock = socket.socket(socket.AF_INET,socket.SOCK_DGRAM)      # For UDP

udp_host = socket.gethostname()                      # Host IP
udp_port = 12345                                  # specified port to connect

msg = "UDP Program!"
print "UDP target IP:", udp_host
print "UDP target Port:", udp_port

sock.sendto(msg.encode(),(udp_host,udp_port))
```

Practice Programs:

1A) Write a program where client can send a message to the server and the server can receive the message and send, or echo, it back to the client.

Echo Client:

```
import socket

HOST = '127.0.0.1'  # The server's hostname or IP address
PORT = 2053      # The port used by the server

with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
    s.connect((HOST, PORT))
    s.sendall(b'Hello, world')
    data = s.recv(1024)
    print('Received Connection')
    print('Server:', data.decode())
```

Echo Server:

```
import socket

HOST = '127.0.0.1' # Standard loopback interface address (localhost)
PORT = 2053     # Port to listen on (non-privileged ports are > 1023)

with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
    s.bind((HOST, PORT))
    s.listen()
    conn, addr = s.accept()

    with conn:
        print('Connected by', addr)
        while True:
            data = conn.recv(1024)
            if  data:
                print("Client: ",data.decode())
            data = input("Enter message to client:");
            if not data:
                break;
            # sending message as bytes to client.
            conn.sendall(bytearray(data, 'utf-8'));

    conn.close()
```

2A) Write a program to create TCP time server in Python

Time Client:

```
#client.py
import socket

# create a socket object
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# get local machine name
host = socket.gethostname()
port = 9991
# connection to hostname on the port.
s.connect((host, port))
# Receive no more than 1024 bytes
tm = s.recv(1024)
print(' Current time from Sever :', tm.decode())
s.close()
```

Time Server:

```
# server.py
import socket
import time

# create a socket object
serversocket = socket.socket(
                socket.AF_INET, socket.SOCK_STREAM)

# get local machine name
host = socket.gethostname()

port = 9991

# bind to the port
serversocket.bind((host, port))

# queue up to 5 requests
serversocket.listen(5)

while True:
    # establish a connection
    clientsocket,addr = serversocket.accept()

    print("Got a connection from %s" % str(addr))
    currentTime = time.ctime(time.time()) + "\r\n"
    clientsocket.send(currentTime.encode('ascii'))
    clientsocket.close()
```

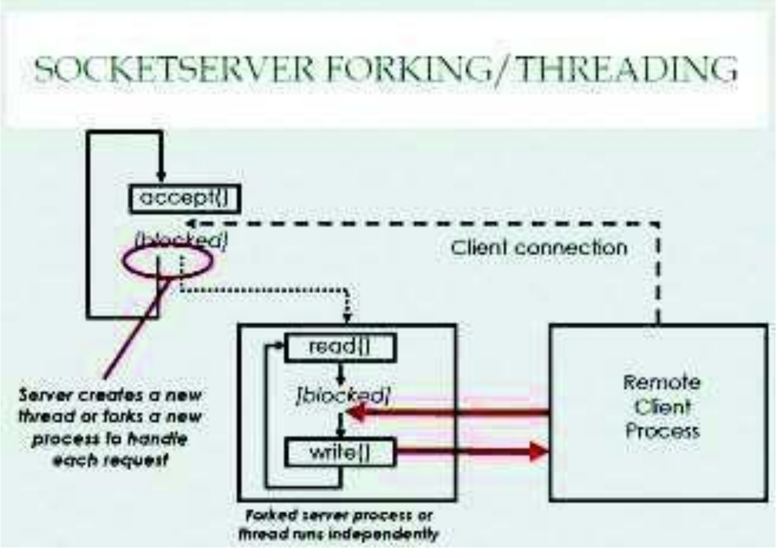
3A) Write a TCP chat server in python using socket programming.

Client Chat:

```
import socket

HOST = '127.0.0.1' # Standard loopback interface address (localhost)
PORT = 31621    # Port to listen on (non-privileged ports are > 1023)
s = socket.socket()
name = input(str("\nEnter your name: ")) print("\nTrying

to connect to ", HOST, "(", PORT, ")\n")

s.connect((HOST, PORT))
print("Connected...\n")

s.send(name.encode())
s_name = s.recv(1024)
s_name = s_name.decode()
print(s_name, "has joined the chat room\nEnter [e] to exit chat room\n")
while True:
    message = s.recv(1024)
    message = message.decode()
    print(s_name, ":", message)
    message = input(str("Me : "))
    if message == "[e]":
        message = "Left chat room!"
        s.send(message.encode())
        print("\n")
        break
    s.send(message.encode())
```

Server Chat:

```
# server.py
import socket
HOST = '127.0.0.1' # Standard loopback interface address (localhost)
PORT = 31621    # Port to listen on (non-privileged ports are > 1023)

s = socket.socket()

s.bind((HOST, PORT))

s.listen()
print("\nWaiting for incoming connections...\n")
conn, addr = s.accept()
print("Received connection from ", addr[0], "(", addr[1], ")\n")

s_name = conn.recv(1024)
s_name = s_name.decode()
print(s_name, "has connected to the chat room\nEnter [e] to exit chat room\n")
name = input(str("Enter your name: "))
conn.send(name.encode())

while True:
    message = input(str("Me : "))
    if message == "[e]":
        message = "Left chat room!"
        conn.send(message.encode())
        print("\n")
        break
    conn.send(message.encode())
    message = conn.recv(1024)
    message = message.decode()
    print(s_name, ":", message)
```


SOCKETSERVER FORKING/THREADING
accept()
(blocked)
Client connection
read()
[blocked]
write()
Remote Client Process
Server creates a new thread or forks a new process to handle each request
Forked server process or thread runs independently

4A. Forking/ Threading (Concurrent Server)

```
 import socket

ClientSocket = socket.socket()
host = '127.0.0.1'
port = 11596

print('Waiting for connection')
try:
    ClientSocket.connect((host, port))
except socket.error as e:
    print(str(e))

Response = ClientSocket.recv(1024)
while True:
    Input = input('Client Say Something: ')
    ClientSocket.send(str.encode(Input))
    Response = ClientSocket.recv(1024)
    print('From Server : ' + Response.decode())

ClientSocket.close()
```

4B. Server Program

```
import socket
import os
from _thread import *

ServerSocket = socket.socket()
host = '127.0.0.1'
port = 11596
ThreadCount = 0
try:
    ServerSocket.bind((host, port))
except socket.error as e:
    print(str(e))

print('Waitiing for a Connection..')
ServerSocket.listen(5)

def threaded_client(connection):
    connection.send(str.encode('Welcome to the Server'))
    while True:
        data = connection.recv(2048)
        print('Received from client :' + str(ThreadCount) +data.decode())
        Inputs = input('Server Says: ')
        if not data:
            break
        connection.sendall(Inputs.encode())
    connection.close()
```

```
while True:
    Client, address = ServerSocket.accept()
    print('Connected to: ' + address[0] + ':' + str(address[1]))
    start_new_thread(threaded_client, (Client, ))
    ThreadCount += 1
    print('Thread Number: ' + str(ThreadCount))
ServerSocket.close()
```

Lab Exercise:

1. Write a UDP time server to display the current time and day.

2. Write a UDP simple chat program for message send and receive.

Sample Output:

Client Side

```
     Do Ctrl+c to exit the program !!
     Type some text to send =>Hi
     1. Client Sent :  Hi
     2. Client received :  Hello
```

Server Side:

```
Do Ctrl+c to exit the program !!
####### Server is listening #######
 2. Server received:  Hi
Type some text to send => Hello
 1. Server sent :  Hello
####### Server is listening #######
```

3. Write a TCP/UDP peer to peer chat system between two different machines.

---

4. Try to debug the error in the code and execute it.

Client:

```
import socket

    serverIP = 'localhost'
    serverPort = 16000

    clientSock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    clientSock.connect((serverIP, serverPort))

    message = raw_input("Input integers with space in between: ")
    message2 = raw_input("Enter the length of the set: ")

    clientSock.send(message)
    clientSock.send(message2)

    data = clientSock.recv(1024)

    temp = [float(x) for x in data.split(' ')]

    print("The total of all numbers is: " + str(temp[0]))
    print("The lowest number is: " + str(temp[1]))
    print("The highest number is: " + str(temp[2]))
    print("The mean is: " + str(temp[3]))

    clientSock.close()
```

```
import socket


    serverIP = 'localhost'

    serverPort = 16000


    serverSock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

    serverSock.bind((serverIP, serverPort))

    serverSock.listen(1)


    print("TCP server has started and is ready to receive")


    w ile 1:

        connection, addr = serverSock.accept()

        data = connection.recv(1024)


        if not data: break


        temp = [float(x) for x in data.split(' ')]

        print "Received data:", temp


        length = len(temp)

        maximum = max(temp)

        minimum = min(temp)

        total = sum(temp)

        mean = total/length


        msg = str(total) + " " + str(minimum) + " " + str(maximum) + " " + str(mean)
        connection.send(str(msg))
```

- Below is an example input from clientTCP side:
- `Input integers with space in between: 5 4 6 9 3.4`
- Next, the user will enter the length of the above set when prompted from clientUDP side:
- `Enter the length of the set: 5`
- Next, you will notice a screen output on the serverTCP side as follows:
- `TCP server has started and is ready to receive`
- `Received data: [5.0, 4.0, 6.0, 9.0, 3.4]`
- Finally you will should see an output on the clientTCP side as follows:
- `The total of all numbers is: 27.4`
- `The lowest number is: 3.4`
- `The highest number is: 9.0`

```
The mean is: 5.48
```

LAB – 5

MAP REDUCE PROGRAMS AND PRACTICE -I USING PYTHON

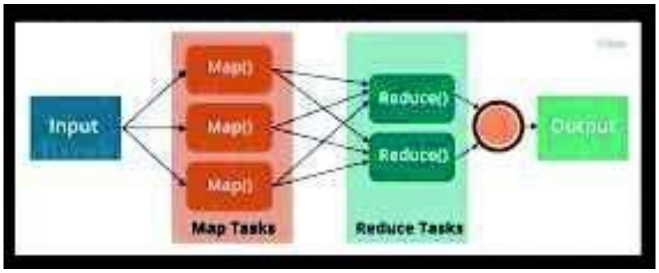
Lab – 5

MapReduce Programming using Python - I

MapReduce: Programming Model and Implementations:

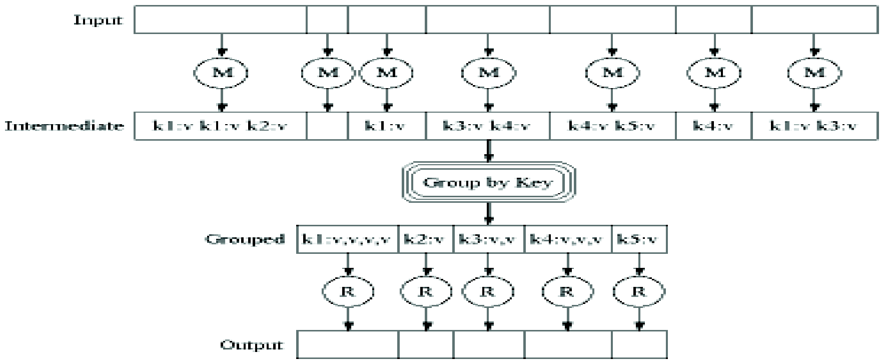
Hadoop is a framework that allows to process and store huge data sets. Basically, Hadoop can be divided into two parts: processing and storage. So, MapReduce is a programming model whichallows you to process huge data stored in Hadoop. When you install Hadoop in a cluster, we get MapReduce as a service where you can write programs to perform computations in data in parallel and distributed fashion.

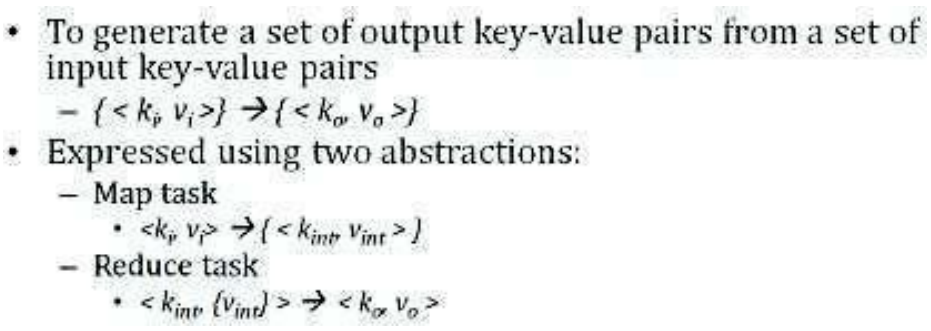
Map – Reduce Implementation:



MapReduce is a programming framework that allows us to perform distributed and parallel processing on large data sets in a distributed environment. MapReduce consists of two distinct tasks – Map and Reduce. As the name MapReduce suggests, reducer phase takes place after mapper phase has been completed. So, the first is the map job, where a block of data is read and processedto produce key-value pairs as intermediate outputs. The output of a Mapper or map job (key-value pairs) is input to the Reducer. The reducer receives the key-value pair from multiple map jobs. Then, the reducer aggregates those intermediate data tuples (intermediate key-value pair) into a smaller set of tuples or key-value pairs which is the final output.

Execution:





- To generate a set of output key-value pairs from a set of input key-value pairs
  - $\{<k_i, v_i>\} \rightarrow \{<k_o, v_o>\}$
- Expressed using two abstractions:
  - Map task
    - $<k_i, v_i> \rightarrow \{<k_{int}, v_{int}>\}$
  - Reduce task
    - $<k_{int}, \{v_{int}\}> \rightarrow <k_o, v_o>$

The Wordcount Example

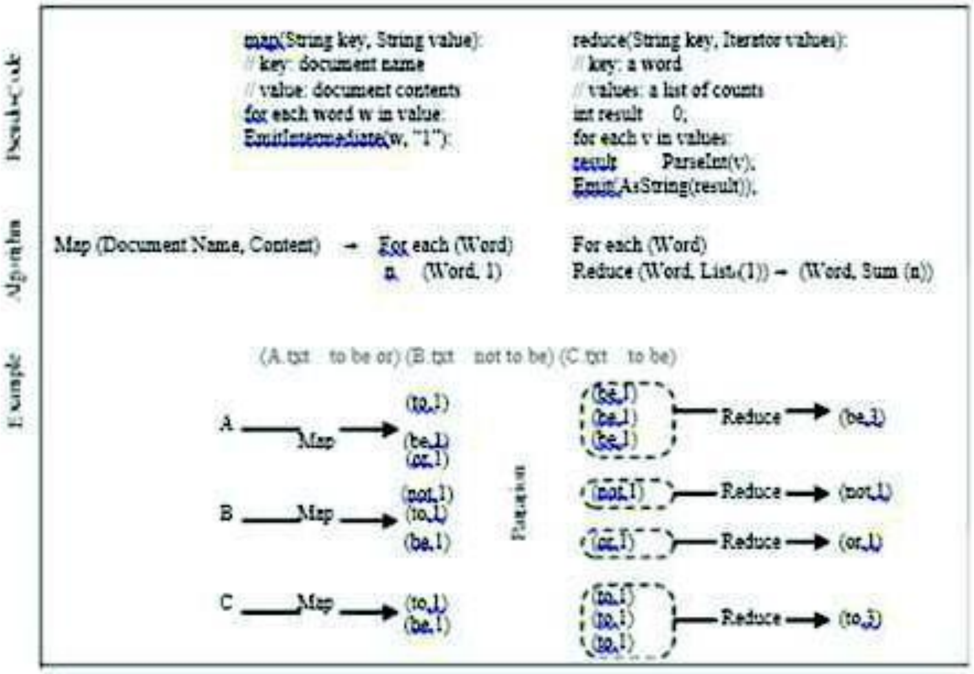
The Wordcount application counts the number of occurrences of each word in a large collection of documents.

The steps of the process are briefly described as follows:

→ The input is read and broken up into key/value pairs (e.g., the Map function emits a word and its associated count of occurrence, which is just "1").

→ The pairs are partitioned into groups for processing, and they are sorted according to their key as they arrive for reduction.

→ Finally, the key/value pairs are reduced, once for each unique key in the sorted list, to produce a combined result (e.g., the Reduce function sums all the counts emitted for a particular word).



```
map(String key, String value):
// key: document name
// value: document contents
for each word w in value:
EmitIntermediate(w, "1");
```

```
reduce(String key, Iterator values):
// key: a word
// values: a list of counts
int result    0;
for each v in values:
result     ParseInt(v);
Emit(AsString(result));
```

Map (Document Name, Content) → For each (Word)
n (Word, 1)

For each (Word)
Reduce (Word, List (1)) → (Word, Sum (n))

(A.txt to be or) (B.txt not to be) (C.txt to be)

Another Example:

```
map(String input_key, String input_value):
  // input_key: document name
  // input_value: document contents
  for each word w in input_value:
    EmitIntermediate(w, "1");
```

<“Sam”, “1”>, <“Apple”, “1”>, <“Sam”, “1”>, <“Mom”, “1”>,
<“Sam”, “1”>, <“Mom”, “1”>,

```
reduce(String output_key, Iterator intermediate_values):
  // output_key: a wo
  // output_values: a list of counts
  int result = 0;
  for each v in intermediate_values:
    result += ParseInt(v);
  Emit(AsString(result));
```

<“Sam” , [“1”,”1”,”1”]>, <“Apple” , [“1”]>, <“Mom” , [“1”, “1”] >

“3”
“1”
“2”

1. Write a basic wordcount program.

Sample Pseudocode:

Mapper:

```
void Map (key, value)
{
        for each word x in value:
                emit(x, 1);
}
```

Reducer:

```
void Reduce (keyword, <list_val>)
{
        for each x in <list_val>:
                sum+=x;
                emit(keyword, sum);
}
```

Python Programs:

```
#!/usr/bin/env python
"""mapper.py"""

import sys

# input comes from STDIN (standard input)
for line in sys.stdin:
    # remove leading and trailing whitespace
    line = line.strip()
    # split the line into words
    words = line.split()
    # increase counters
    for word in words:
        # write the results to STDOUT (standard output);
        # what we output here will be the input for the
        # Reduce step, i.e. the input for reducer.py
        #
        # tab-delimited; the trivial word count is 1
        print '%s\t%s' % (word, 1)
```

```
#!/usr/bin/env python
"""reducer.py"""

from operator import itemgetter
import sys
```

```
current_word = None
current_count = 0
word = None

# input comes from STDIN
for line in sys.stdin:
    # remove leading and trailing whitespace
    line = line.strip()

    # parse the input we got from mapper.py
    word, count = line.split('\t', 1)

    # convert count (currently a string) to int
    try:
        count = int(count)
    except ValueError:
        # count was not a number, so silently
        # ignore/discard this line
        continue

    # this IF-switch only works because Hadoop sorts map output
    # by key (here: word) before it is passed to the reducer
    if current_word == word:
        current_count += count
    else:
        if current_word:
            # write result to STDOUT
            print '%s\t%s' % (current_word, current_count)
        current_count = count
        current_word = word
# do not forget to output the last word if needed!
if current_word == word:
    print '%s\t%s' % (current_word, current_count)
```

Test your code locally:

```
# Test mapper.py and reducer.py locally first
# very basic test (using only mapper.py)
hduser@ubuntu:~$ echo "a a a a v v f f hh hh fg tg fg  gt nnn ccc ddd nnn ddd"|python3 mapper.py
a       1
a       1
a       1
a       1
v       1
v       1
f       1
f       1
hh      1
hh      1
fg      1
tg      1
fg      1
gt      1
nnn     1
ccc     1
ddd     1
nnn     1
```

```
ddd         1

# very basic test (using mapper.py and reducer.py)

hduser@ubuntu:~$ echo "a a a a v v f f hh hh fg tg fg   gt nnn ccc ddd nnn ddd"|python3
mapper.py|python3 reducer.py

a           4

v           2

f           2

hh          2

fg          1

tg          1

fg          1

gt          1

nnn         1

ccc         1

ddd         1

nnn         1

ddd         1

# very basic test (use mapper.py , sort the output and use reducer.py)

hduser@ubuntu:~$ echo "a a a a v v f f hh hh fg tg fg   gt nnn ccc ddd nnn ddd"|python3
mapper.py|sort|python3 reducer.py

a           4

ccc         1

ddd         2

f           2

fg          2

gt          1

hh          2

nnn         2

tg          1
```

```
v           2
```

# very basic test (use mapper.py , sort the output and use reducer.py) and write it to text file)

```
hduser@ubuntu:~$ echo "a a a a v v f f hh hh fg tg fg   gt nnn ccc ddd nnn ddd"|python3 mapper.py|sort|python3 reducer.py > out.txt

hduser@ubuntu:~$ cat out.txt
```

To extract words from any dataset or any file…. (use the proper path of file in the command)

```
hduser@ubuntu:~$ cat /home/xxx/Desktop/HR.txt | python3 mapper.py | sort | python3 reducer.py > out_HR.txt

shduser@ubuntu:~$ cat out_HR.txt
```

Exercise 1: Try the above word count program for the Heart Disease dataset, covid_19_data dataset, example dataset and German Credit dataset.

Students can decide their own way of displaying results (can work on any columns in the dataset) on the dataset mentioned.

---

2. MapReduce program to find frequent words

freqmap1.py

```python
#!/usr/bin/env python
# A basic mapper function/program that
# takes whatever is passed on the input and
# outputs tuples of all the words formatted
# as (word, 1)
from __future__ import print_function
import sys

# input comes from STDIN (standard input)
for line in sys.stdin:

    # create tuples of all words in line
    L = [ (word.strip().lower(), 1 ) for word in line.strip().split() ]

    # increase counters
    for word, n in L:
        # write the results to STDOUT (standard output);
        # what we output here will be the input for the
        # Reduce step, i.e. the input for reducer.py
        #
        # tab-delimited; the trivial word count is 1
        print( '%s\t%d' % (word, n) )
```

freqred1.py

```
#!/usr/bin/env python
# reducer.py
from __future__ import print_function
import sys

lastWord = None
sum = 0

for line in sys.stdin:
    word, count = line.strip().split('\t', 1)
    count = int(count)

    if lastWord==None:
        lastWord = word
        sum = count
        continue

    if word==lastWord:
        sum += count
    else:
        print( "%s\t%d" % ( lastWord, sum ) )
        sum = count
        lastWord = word

# output last word
if lastWord == word:
    print( '%s\t%s' % (lastWord, sum ) )
```

freqmap2.py

```
#!/usr/bin/env python
# A basic mapper function/program that
# takes whatever is passed on the input and
# outputs tuples of all the words formatted
# as (word, 1)
from __future__ import print_function
import sys

# input comes from STDIN (standard input)
for line in sys.stdin:

    word, count = line.strip().split('\t', 1)
    count = int(count)
    print( '%d\t%s' % (count, word) )
```

---

freqred2.py

```
#!/usr/bin/env python
# reducer.py
from __future__ import print_function
import sys

mostFreq = []
currentMax = -1

for line in sys.stdin:
      count, word = line.strip().split('\t', 1)
      count = int(count)
      if count > currentMax:
            currentMax = count
            mostFreq = [ word ]
      elif count == currentMax:
            mostFreq.append( word )

# output mostFreq word(s)
for word in mostFreq:
    print( '%s\t%s' % ( word, currentMax ) )
```

```
hduser@ubuntu:~$ echo "foo foo foo labs labs labs quux labs foo bar quux" |python3
freqmap1.py |sort|python3 freqred1.py


 bar     1

 foo     4

 labs    4

 quux    2



 hduser@ubuntu:~$ echo "foo foo foo labs labs labs quux labs foo bar quux" |
 python3 freqmap1.py |sort|python3 freqred1.py|python3 freqmap2.py

 1       bar

 4       foo

 4       labs

 2       quux

 hduser@ubuntu:~$ echo "foo foo foo labs labs labs quux labs foo bar quux" |
 python3 freqmap1.py |sort|python3 freqred1.py|python3 freqmap2.py|sort

 1       bar

 2       quux

 4       foo

 4       labs

 hduser@ubuntu:~$ echo "foo foo foo labs labs labs quux labs foo bar quux" |
 python3  freqmap1.py  |sort|python3  freqred1.py|python3  freqmap2.py|sort|python3
 freqred2.py

 foo     4

 labs    4
```

Exercise 2: Try the above frequent word count program for the Heart Disease dataset, covid_19_data dataset, example dataset and German Credit data.

Students can decide their own way of displaying results (can work on any columns in the dataset) on the dataset mentioned.

3. MapReduce program to explore the dataset and perform the filtering (typically creating key/value pairs) by mapper and perform the count and summary operation on the instances.

Itemmap.py

```
#!/usr/bin/python
"""

INPUT: Transactions of products in multiple stores and location; these can also be passed to STDIN

    Format of each line is: date\ttime\tstore location\titem description\tcost\tmethod of payment

OUTPUT: E.g.

        Las Vegas       208.97

        Miami   84.11

        Tucson  489.93

        San Francisco   388.3

        Dallas  145.63

        Tampa   353.23

        Washington      481.31

        San Jose        492.8

        Newark  410.37

        Memphis 354.44

        Jersey City     369.07

        Plano   4.65

        Buffalo 337.35

        Louisville      213.64

        Miami   154.64

        ...
"""
```

```
#import string
import fileinput


for line in fileinput.input():
    data = line.strip().split("\t")
    if len(data) == 6:
        date, time, location, item, cost, payment = data
        print ("{0}\t{1}".format(location, cost))


#can try with different instances.....
               #print ("{0}\t{1}".format(payment, cost))
        #print ("{0}\t{1}".format(item, cost))
```

itemred.py

```
#!/usr/bin/python


"""
INPUT: Output from mapper.py
        Format of each line is: location\tcost
OUTPUT: E.g.
            50 12268.16
"""
import fileinput


transactions_count = 0
sales_total = 0


for line in fileinput.input():
    data = line.strip().split("\t")

    if len(data) != 2:
        # Something has gone wrong. Skip this line.
        continue

    current_key, current_value = data

    transactions_count += 1
    sales_total += float(current_value)

print (transactions_count, "\t", sales_total)
```

Mapper Output:

```
hduser@ubuntu: ~ $ cat /home/shanthi/Desktop/example.txt | python3 itemmap.py| sort
Atlanta 189.22
Aurora    82.38
Austin    48.09
Birmingham        1.64
Boston    397.21
Buffalo   337.35
Buffalo   386.56
Chicago   364.53
Chicago   431.73
Cincinnati        129.6
Cincinnati        1.41
Cincinnati        288.32
Cincinnati        443.78
Corpus Christi    157.91
…….
```

Reducer Output:

```
hduser@ubuntu:~$ cat /home/shanthi/Desktop/example.txt | python3 itemmap.py |sort| python3 itemred.py
50          12268.159999999996      # displayed total instances and its sum
```

Exercise 3: Try the above ‘Item explore and count program’ for the Heart Disease dataset, covid_19_data dataset, example dataset and German Credit dataset.

Students can decide their own way of displaying results (can work on any columns in the dataset) on the dataset mentioned.

LAB – 6

MAP REDUCE PROGRAMS AND PRACTICE -II USING PYTHON

Lab – 6

MapReduce Programming using Python - II

4. Write a mapper and reducer program for word count by defining separator instead of using “\t”.

sepmap.py

```
#!/usr/bin/env python
"""A more advanced Mapper, using Python iterators and generators."""


import sys


def read_input(file):
    for line in file:
        # split the line into words
        yield line.split()


def main(separator='\t'):
    # input comes from STDIN (standard input)
    data = read_input(sys.stdin)
    for words in data:
        # write the results to STDOUT (standard output);
        # what we output here will be the input for the
        # Reduce step, i.e. the input for reducer.py
        # tab-delimited; the trivial word count is 1
        for word in words:
            print ('%s%s%d' % (word, separator, 1))

if __name__== "__main__":
    main()
```

sepred.py

```
#!/usr/bin/env python
"""A more advanced Reducer, using Python iterators and generators."""

from itertools import groupby
from operator import itemgetter
import sys

def read_mapper_output(file, separator='\t'):
    for line in file:
        yield line.rstrip().split(separator, 1)

def main(separator='\t'):
    # input comes from STDIN (standard input)
    data = read_mapper_output(sys.stdin, separator=separator)
    # groupby groups multiple word-count pairs by word,
    # and creates an iterator that returns consecutive keys and their group:
    #  current_word - string containing a word (the key)
    #  group - iterator yielding all ["&lt;current_word&gt;", "&lt;count&gt;"] items
    for current_word, group in groupby(data, itemgetter(0)):
```

```
    try:
        total_count = sum(int(count) for current_word, count in group)
        print ("%s%s%d" % (current_word, separator, total_count))
    except ValueError:
        # count was not a number, so silently discard this item
        pass

if __name__== "__main__":
  main()
```

Note:

Why Separator ?

Eg:

```
print('G','F', sep=", end=")print('G')

#\n provides new line after printing the year

print('09','12','2016', sep= '-', end='\n')
print('prtk','agarwal', sep= ' ' , end='@')
print('manipal')
```

Output:

```
GFG
09-12-2016
prtkagarwal@manipal
```

Output:

```
hduser@ubuntu:~$ echo " Time is gold Time is  Time  gold" | python3 sepmap.py|python3 sepred.py

Time   ->1

is     ->1

gold   ->1

Time   ->1

is     ->1
```

```
Time    ->1

gold    ->1

hduser@ubuntu:~$ echo " Time is gold Time is Time gold" | python3 sepmap.py|sort|python3 sepred.py

gold    ->2

is      ->2

Time    →3
```

Exercise 4: Try to include separator using map reducing for the output of Heart Disease dataset, covid_19_data dataset, example dataset and German Credit dataset.

---

5. Write a map reduce program that returns the cost of the item that is most expensive, for each location in the dataset example.txt

itemmap_expensive.py

```
#!/usr/bin/python

“""

INPUT: Transactions of products in multiple stores and location; these can also be passed to STDIN

        Format of each line is: date\ttime\tstore location\titem description\tcost\tmethod of payment

OUTPUT: E.g.

            Las Vegas       208.97

            Miami   84.11

            Tucson  489.93

            San Francisco   388.3

            Dallas  145.63

            Tampa   353.23

            Washington      481.31

            San Jose        492.8

            Newark  410.37
            Memphis 354.44

            Jersey City     369.07

            Plano  4.65

            Buffalo 337.35

            Louisville      213.64

            Miami  154.64

            ...

"""


import fileinput


for line in fileinput.input():

    data = line.strip().split("\t")

    if len(data) == 6:

        date, time, location, item, cost, payment = data

        print ("{0}\t{1}".format(location, cost))
```

itemred_expensive.py

```
#!/usr/bin/python


"""

INPUT: Output from mapper.py

        Format of each line is: location\tcost

OUTPUT: E.g.

            Atlanta     189.22
        Aurora	82.38
        Austin	48.09
        Birmingham	1.64
        Boston	397.21
        Buffalo	386.56
"""
import fileinput

max_value = 0
old_key = None

for line in fileinput.input():

    data = line.strip().split("\t")

    if len(data) != 2:
        # Something has gone wrong. Skip this line.
        continue

    current_key, current_value = data

    # Refresh for new keys (i.e. locations in the example context)
    if old_key and old_key != current_key:
        print (old_key, "\t", max_value)
        old_key = current_key
        max_value = 0
    old_key = current_key

    if float(current_value) > float(max_value):

        max_value = float(current_value)


if old_key != None:

    print (old_key, "\t", max_value)
```

```
Output:

hduser@ubuntu:~$ cat /home/shanthi/Desktop/example.txt | python3 itemmap1.py|sort

Atlanta189.22

Aurora 82.38

Austin 48.09

Birmingham 1.64

Boston 397.21

Buffalo         337.35

Buffalo         386.56    # selects max value

Chicago         364.53

Chicago         431.73  …… # selects max value


hduser@ubuntu:~$ cat /home/shanthi/Desktop/example.txt | python3 itemmap1.py|sort|python3
itemred1.py

Atlanta         189.22

Aurora          82.38

Austin 48.09

Birmingham     1.64
```

```
Boston          397.21

Buffalo         386.56 # selected max value

Chicago         431.73  # selected max value
```

Exercise 5: Try to apply finding max value using map reduce concept for the output of Heart Disease dataset, covid_19_data dataset, example dataset and German Credit dataset.

Students can decide their own way of displaying results (can work on any columns in the dataset) on the dataset mentioned.

Exercise 6: Write a map reduce program that returns the highest number of confirmed Covid cases for each Country/ Region and display the summary operation of confirmed cases in the dataset covid_data_lab_ds.csv

Exercise 7: Write a MapReduce program to count even or odd numbers in randomly generated natural numbers.

****

LAB – 7

CLOCK SYNCHRONIZATION

CLOCK SYNCHRONIZATION

I. Introduction to Clock Synchronization

Time notion: Each computer is equipped with a physical (hardware) clock.
At time t, the operating system (OS) of a process i reads the hardware clock H (t) of the processor, generates the software clock C=a H(t)+b, as a counter incremented by ticks of an oscillator.

Time in Distributed System (DS): Time is a key factor in a DS to analyse how distributed execution evolve.

Problems: Lacking of a global reference time: it's hard to know the state of a process during a distributed computation. However, it's important for processes to share a common time notion.

The techniques used to coordinate a common time notion among processes is known as Clock Synchronization.

Clock Synchronization: The hardware clock of a set of computers may differ because they count time with different frequencies.

Clock Synchronization faces this problem by means of synchronization algorithms

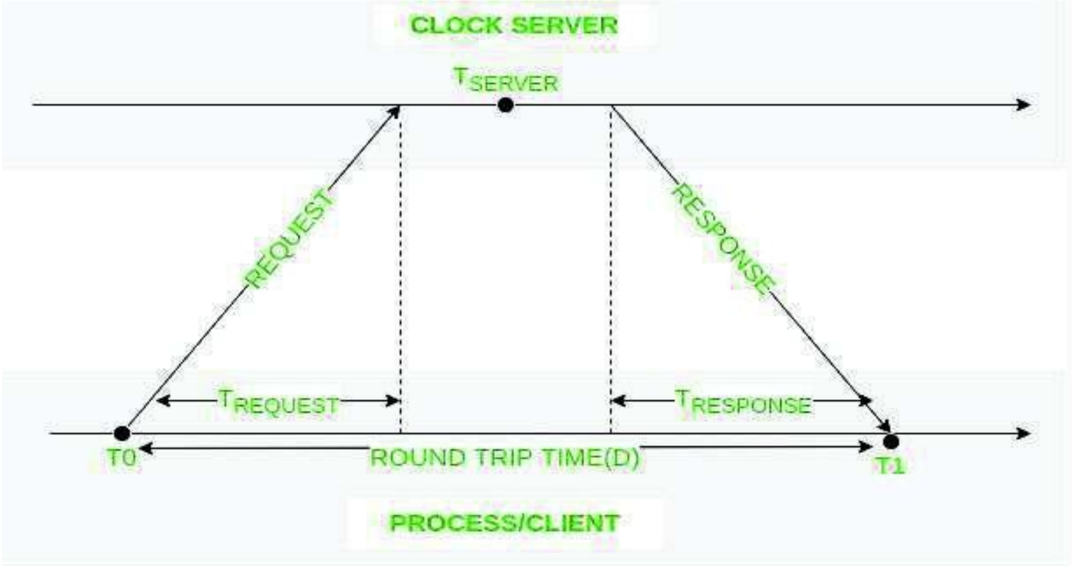
- Standard communication infrastructure
- No additional hardware

Clock synchronization algorithms

- External
- Internal
- Heartbeat (pulse)

External clock synchronization:
Is the one in which an external reference clock is present. It is used as a reference and the nodes in the system can set and adjust their time accordingly.
Internal clock synchronization: Is the one in which each node shares its time with other nodes and all the nodes set and adjust their times accordingly.

II. **Cristian's algorithm: Cristian's Algorithm** is a clock synchronization algorithm is used to synchronize time with a time server by client processes. This algorithm works well with low-latency networks where Round Trip Time is short as compared to accuracy while redundancy prone distributed systems/applications do not go hand in hand with this algorithm. Here Round Trip Time refers to the time duration between start of a Request and end of corresponding Response.



Algorithm:

1) The process on the client machine sends the request for fetching clock time (time at server) to the Clock Server at time.

2) The Clock Server listens to the request made by the client process and returns the response in form of clock server time.

3) The client process fetches the response from the Clock Server at time and calculates the synchronised client clock time using the formula given below.

$T_{CLIENT} = T_{SERVER} + (T1-T0)/2$

T_{CLIENT} = synchronised clock time

T_{SERVER} = clock time returned by the server

T0 = time at which request was sent by the client process

T1= time at which response was received by the client process

III. **Berkeley's algorithm**: Berkeley's Algorithm is a clock synchronization technique used in distributed systems. The algorithm assumes that each machine node in the network either doesn't have an accurate time source or doesn't possess an UTC server.

Algorithm:

1) An individual node is chosen as the master node from a pool nodes in the network. This node

is the main node in the network which acts as a master and rest of the nodes act as slaves. Master node is chosen using a election process/leader election algorithm.

2) Master node periodically pings slaves nodes and fetches clock time at them using Cristian's algorithm.

3) Master node calculates average time difference between all the clock times received and the clock time given by master's system clock itself. This average time difference is added to the current time at master's system clock and broadcasted over the network.
Pseudocode for above step:

```
# receiving time from all slave nodes
repeat_for_all_slaves:
 time_at_slave_node = receive_time_at_slave()
 # calculating time difference
 time_difference = time_at_master_node - time_at_slave_node
# average time difference calculation
average_time_difference = sum(all_time_differences) / number_of_slaves
synchronized_time = current_master_time + average_time_difference
# broadcasting synchronized to whole network
broadcast_time_to_all_slaves(synchronized_time)
```

Diagram below illustrates how the master sends request to slave nodes.

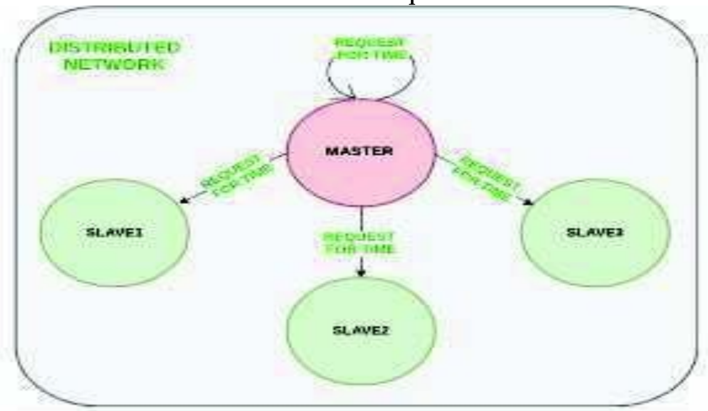


Diagram below illustrates how slave nodes send back time given by their system clock.

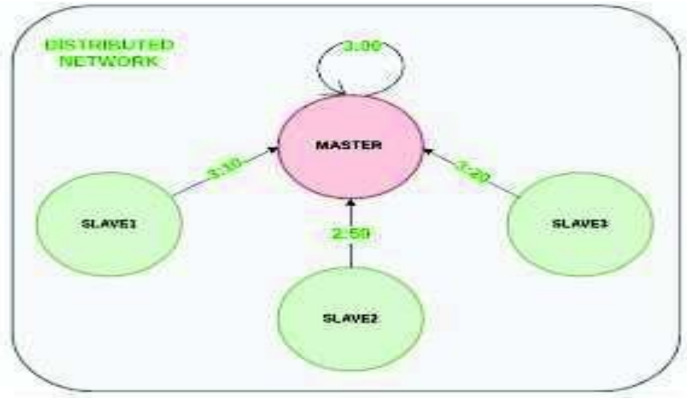
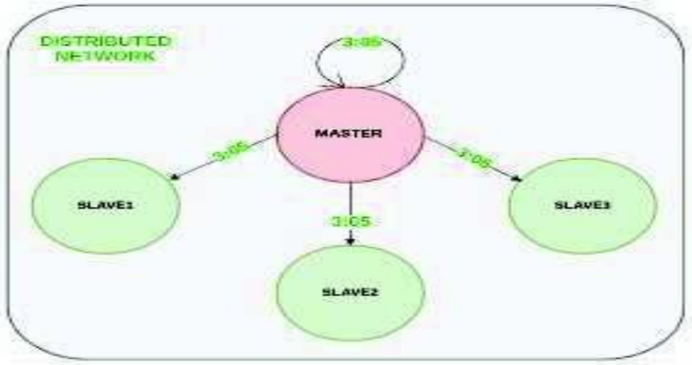


Diagram below illustrates the last step of Berkeley's algorithm.



IV. Solved examples:

A. Cristian's algorithm

I) To initiate a prototype of a clock server on local machine:

Server:

```
# Python3 program imitating a clock server

import socket
import datetime
import time
# function used to initiate the Clock Server
def initiateClockServer():
        s = socket.socket()
        print("Socket successfully created")
        # Server port
        port = 8011
```

```
    s.bind((", port))
    # Start listening to requests
    s.listen(5)
    print("Socket is listening...")
    # Clock Server Running forever
    while True:
    # Establish connection with client
        connection, address = s.accept()
        print('Server connected to', address)
    # Respond the client with server clock time
        connection.send(str(datetime.datetime.now()).encode())
    # Close the connection with the client process
    connection.close()
# Driver function
if__name__== '__main__':
    # Trigger the Clock Server
    initiateClockServer()
```

Output Sever Side:

```
Ubuntu@ubuntu:~$ python3 cris_ser.py
Socket successfully created
Socket is listening...
Server connected to ('127.0.0.1', 42310)
```

II) **Code below is used to initiate a prototype of a client process on local machine:**
# Python3 program imitating a client process

```
import socket
import datetime
from dateutil import parser
from timeit import default_timer as timer
```

```
# function used to Synchronize client process time
def synchronizeTime():

    s = socket.socket()

    # Server port
    port = 8011

    # connect to the clock server on local computer
    s.connect(('127.0.0.1', port))

    request_time = timer()

    # receive data from the server
    server_time = parser.parse(s.recv(1024).decode())
    response_time = timer()
    actual_time = datetime.datetime.now()

    print("Time returned by server: " + str(server_time))

    process_delay_latency = response_time - request_time

    print("Process Delay latency: " + str(process_delay_latency) + " seconds")

    print("Actual clock time at client side: " + str(actual_time))

    # synchronize process client clock time
    client_time = server_time + datetime.timedelta(seconds = (process_delay_latency) / 2)
    print("Synchronized process client time: " + str(client_time))

    # calculate synchronization error
    error = actual_time - client_time
    print("Synchronization error : " + str(error.total_seconds()) + " seconds")

    s.close()



# Driver function
if__name__== '__main__':

    # synchronize time using clock server
    synchronizeTime()
```

Output Client Side:

```
Time returned by server: 2021-05-27 17:41:36.223936
Process Delay latency: 0.0008580669999995799 seconds
Actual clock time at client side: 2021-05-27 17:41:36.224587
Synchronized process client time: 2021-05-27 17:41:36.224365
Synchronization error : 0.000222 second
```

B. Berkeley’s algorithm:

Server Side:

```
# Python3 program imitating a clock server

from functools import reduce
from dateutil import parser
import threading
import datetime
import socket
import time


# datastructure used to store client address and clock data
client_data = {}


''' nested thread function used to receive
    clock time from a connected client '''
def startRecieveingClockTime(connector, address):

    while True:
        # recieve clock time
        clock_time_string = connector.recv(1024).decode()
        clock_time = parser.parse(clock_time_string)
        clock_time_diff = datetime.datetime.now() - \
                                                 clock_time

        client_data[address] = {
                        "clock_time"      : clock_time,
                        "time_difference" : clock_time_diff,
                        "connector"       : connector
                        }

        print("Client Data updated with: "+ str(address),
                                              end = "\n\n")
        time.sleep(5)


''' master thread function used to open portal for
    accepting clients over given port '''
def startConnecting(master_server):

    # fetch clock time at slaves / clients
    while True:
        # accepting a client / slave clock client
        master_slave_connector, addr = master_server.accept()
        slave_address = str(addr[0]) + ":" + str(addr[1])

        print(slave_address + " got connected successfully")

        current_thread = threading.Thread(
                         target = startRecieveingClockTime,
                         args = (master_slave_connector,
                                           slave_address, ))
        current_thread.start()


# subroutine function used to fetch average clock difference
def getAverageClockDiff():

    current_client_data = client_data.copy()

    time_difference_list = list(client['time_difference']
                                for client_addr, client
                                    in client_data.items())
    sum_of_clock_difference = sum(time_difference_list, \
                                   datetime.timedelta(0, 0))

    average_clock_difference = sum_of_clock_difference \
                                         / len(client_data)

    return  average_clock_difference

def synchronizeAllClocks():

    while True:

        print("New synchroniztion cycle started.")
        print("Number of clients to be synchronized: " + \
                                     str(len(client_data)))

        if len(client_data) > 0:

            average_clock_difference = getAverageClockDiff()

            for client_addr, client in client_data.items():
                try:
                    synchronized_time = \
                         datetime.datetime.now() + \
                                    average_clock_difference

                    client['connector'].send(str(
                               synchronized_time).encode())
                except Exception as e:
                    print("Something went wrong while " + \
                          "sending synchronized time " + \
                          "through " + str(client_addr))

        else :
            print("No client data." + \
                        " Synchronization not applicable.")

        print("\n\n")

        time.sleep(5)


# function used to initiate the Clock Server / Master Node
def initiateClockServer(port = 8080):

    master_server = socket.socket()
    master_server.setsockopt(socket.SOL_SOCKET,
                                   socket.SO_REUSEADDR, 1)

    print("Socket at master node created successfully\n")

    master_server.bind((", port))

    # Start listening to requests
    master_server.listen(10)
    print("Clock server started...\n")

    # start making connections
    print("Starting to make connections...\n")
    master_thread = threading.Thread(
                          target = startConnecting,
                          args = (master_server, ))
    master_thread.start()

    # start synchroniztion
    print("Starting synchronization parallely...\n")
    sync_thread = threading.Thread(
                            target = synchronizeAllClocks,
                            args = ())
    sync_thread.start()




# Driver function
if__name__== '__main__':

    # Trigger the Clock Server
    initiateClockServer(port = 8080)
```

Output:

```
New synchroniztion cycle started.
Number of clients to be synchronized: 2



Client Data updated with: 127.0.0.1:37624

Client Data updated with: 127.0.0.1:37626
```

Client Side :

```
# Python3 program imitating a client process
from timeit import default_timer as timer
from dateutil import parser
import threading
import datetime
import socket
import time


# client thread function used to send time at client side
def startSendingTime(slave_client):

    while True:
        # provide server with clock time at the client
        slave_client.send(str(
                       datetime.datetime.now()).encode())

        print("Recent time sent successfully",
                                          end = "\n\n")
        time.sleep(5)


# client thread function used to receive synchronized time
def startReceivingTime(slave_client):

    while True:
        # receive data from the server
        Synchronized_time = parser.parse(
                          slave_client.recv(1024).decode())
        print("Synchronized time at the client is: " + \
                                    str(Synchronized_time),
                                    end = "\n\n")



# function used to Synchronize client process time
def initiateSlaveClient(port = 8080):

    slave_client = socket.socket()

    # connect to the clock server on local computer
    slave_client.connect(('127.0.0.1', port))

    # start sending time to server
    print("Starting to receive time from server\n")
    send_time_thread = threading.Thread(
                      target = startSendingTime,
                      args = (slave_client, ))
    send_time_thread.start()



    # start recieving synchronized from server
    print("Starting to recieving " + \
                         "synchronized time from server\n")
    receive_time_thread = threading.Thread(
                       target = startReceivingTime,
                       args = (slave_client, ))
    receive_time_thread.start()
```

```
# Driver function
if___name___== '_main__':

    # initialize the Slave / Client
    initiateSlaveClient(port = 8080)
```

Output:

```
Synchronized time at the client is: 2021-05-27 17:45:29.885369

Recent time sent successfully

Synchronized time at the client is: 2021-05-27 17:45:34.888644

Recent time sent successfully
```

Lab Exercises:

1. The Manipal Foodie is a renowned automated food processing outlet known for its tiffin service to students. The various processes involved are food production, filling and packing. Every day more than 3000 orders are received on an average from the students in manipal. There are total of 4 production lines for orders received from KMC, MIT, TAPMI and SOLS students, each of them has a digital clock which needs to be in synchronization with the master clock. The master clock mounted in the testing lab controls the entire clock system. Design an appropriate solution using Berkeley's algorithm for the above scenario. Assume that the clocks at the institutes are slave/clients.

2. Manipal Buddy is a banking and education application for the students and staff of MIT, Manipal. Mr Vinay, a sixth semester student wants to pay the end semester exams fees for a re-registered course. He simultaneously wishes to register for a course on NPTEL through the app. To register for exam he uses the mobile app whereas to register for NPTEL course he uses his laptop to log in. As he needs to finish both the registrations on the same day, he tries to do both the tasks simultaneously. Analyse and demonstrate using a program how Cristian's algorithm can be used in the above case to synchronize the clocks. Assume the relevant parameters.

References:

1. Mahajan, S. and Shah, S., 2015. *Distributed Computing*. 2nd ed. Oxford University Press, pp.141-209.
2. GeeksforGeeks. 2020. *Geeksforgeeks | A Computer Science Portal For Geeks*. [online] Available at: <https://www.geeksforgeeks.org/> [Accessed 3 April 2020].
3. American-time.com. 2020. *Food Manufacturing Clock Synchronization Case Study | American Time*. [online] Available at: <https://www.american-time.com/industries/manufacturing/case-studies/food-manufacturing> [Accessed 3 April 2020].

LAB – 8

MUTUAL EXCLUSION (ELECTION ALGORITHM)

MUTUAL EXCLUSION (ELECTION ALGORITHM)

ELECTION ALGORITHMS

Theory:

Many algorithms used in the distributed system require a coordinator that performs functions needed by other processes in the system. Election algorithms are designed to choose a coordinator.

Election Algorithms

Election algorithms choose a process from a group of processors to act as a coordinator. If the coordinator process crashes due to some reasons, then a new coordinator is elected on another processor. E.g. coordinator process is picked as a master in Berkeley clock synchronization algorithm. Election algorithm determines, where a new copy of a coordinator should be restarted. Election algorithm assumes that every active process in the system has a unique priority number. The process with the highest priority will be chosen as a new coordinator. Hence, when a coordinator fails, this algorithm elects that active process which has the highest priority number. The active highest selected number is then sent to every active process in the distributed system.

We have two election algorithms for two different configurations of the distributed system.

1. The Bully Algorithm

This algorithm applies to a system where every process can send a message to every other process in the system.

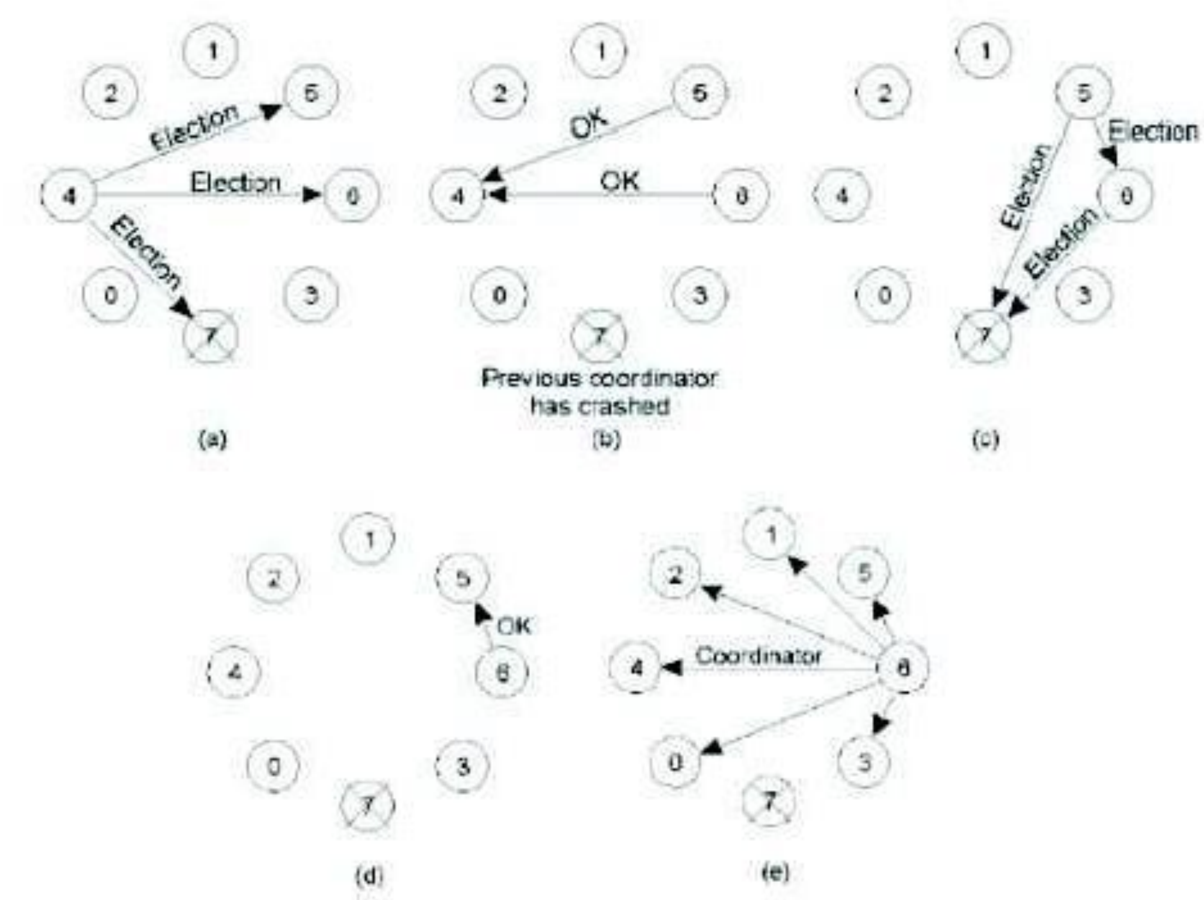
Assumptions

- Each process knows the ID and address of every other process
- Communication is reliable
- A process initiates an election if it just recovered from failure or it notices that the coordinator has failed
- Three types of messages: Election, OK, Coordinator
- Several processes can initiate an election simultaneously
- Need consistent result

Algorithm – Suppose process P sends a message to the coordinator node.

1. If the coordinator node does not respond to it within a time interval T, then it is assumed that the coordinator node has failed.
2. P sends Election messages to all process with higher IDs and awaits OK messages
3. If no OK messages, P becomes coordinator and sends Coordinator messages to all processes with lower IDs

4. If it receives an OK, it drops out and waits for a Coordinator message
5. If a process receives an Election message
   Immediately sends Coordinator message if it is the process with the highest ID
   Otherwise,
      Returns an OK and starts an election
6. If a process receives a Coordinator message, it treats a sender as the coordinator



Bully Algorithm Example

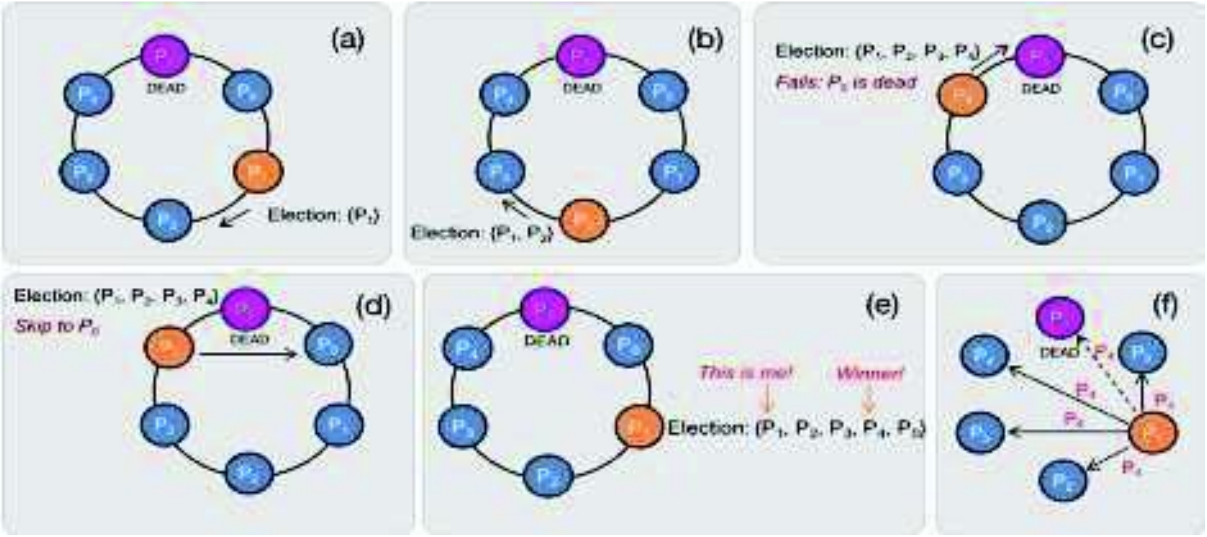
2. The Ring Algorithm

This algorithm applies to systems organized as a ring (logically or physically). In this algorithm, we assume that the link between the processes are unidirectional, and every process can message to the process on its right only.

Assumes that processes are logically ordered in some fashion, and that each process knows the order and who is the coordinator. No token is involved. When a process notices that the coordinator is not responding it sends an ELECTION message with its own id to its downstream neighbour. If that neighbour doesn't acknowledge, it sends it to its neighbour's neighbour, etc. Each station that receives the ELECTION message adds its own id to the list. When the message circulates back to the originator, it selects the highest id in the list and sends a COORDINATOR message announcing the new coordinator. This message circulates once and is removed by the originator. If two elections are held simultaneously (say because two different processes notice simultaneously that the coordinator is dead) then each comes up with the same list and elects the same coordinator. Some time is wasted, but this really hurts nothing.

Algorithm:-

1. Processes are arranged in a logical ring; each process knows the structure of the ring
2. A process initiates an election if it just recovered from failure or it notices that the coordinator has failed
3. The initiator sends Election message to the closest downstream node that is alive
   - – Election message is forwarded around the ring
   - – Each process adds its own ID to the Election message
4. When Election message comes back, initiator picks node with highest ID and sends a Coordinator message specifying the winner of the election
   - – Coordinator message is removed when it has circulated once.



. Ring Algorithm Example

Lab Exercises:

1. Simulate a scenario in distributed systems to implement the Bully Algorithm for choosing a coordinator node amongst the participative nodes of the system after the collapse of the existing coordinator node in the system.

2. Simulate a scenario in distributed systems to implement the Ring Algorithm for choosing a coordinator node amongst the participative nodes of the system after the collapse of the existing coordinator node in the system.

References:

1. Mahajan, S. and Shah, S., 2015. *Distributed Computing*. 2nd ed. Oxford University Press, pp.141-209.
2. GeeksforGeeks. 2020. *Geeksforgeeks | A Computer Science Portal For Geeks*. [online] Available at: <https://www.geeksforgeeks.org/> [Accessed 3 April 2020].
3. American-time.com. 2020. *Food Manufacturing Clock Synchronization Case Study | American Time*. [online] Available at: <https://www.american-time.com/industries/manufacturing/case-studies/food-manufacturing> [Accessed 3 April 2020].

____________________________________-

LAB – 9 & LAB - 10

INSTALLATION OF HADOOP

Hadoop can be installed in your systems in three different modes:

- **Local Standalone mode**
- **Pseudo distributed mode**
- Fully distributed mode (This manual concentrates and contains instruction only on Local and Pseudo distributed mode)

- **Local Standalone mode:**
  This is the default mode. In this mode, all the components of Hadoop, such as NameNode, DataNode, JobTracker and TaskTracker, run on a single Java process.

- **Pseudo-distributed mode:**
  In this mode, a separate JVM is spawned for each of the Hadoop components and they communicate across network sockets, effectively giving a fully functioning minicluster on a single host.

- **Fully Distributed mode:**
  In this mode, Hadoop is spread across multiple machines, some of which will be general-purpose workers and others will be dedicated hosts for components, such as NameNode and JobTracker.

SSH Setup and Key Generation in Ubuntu:

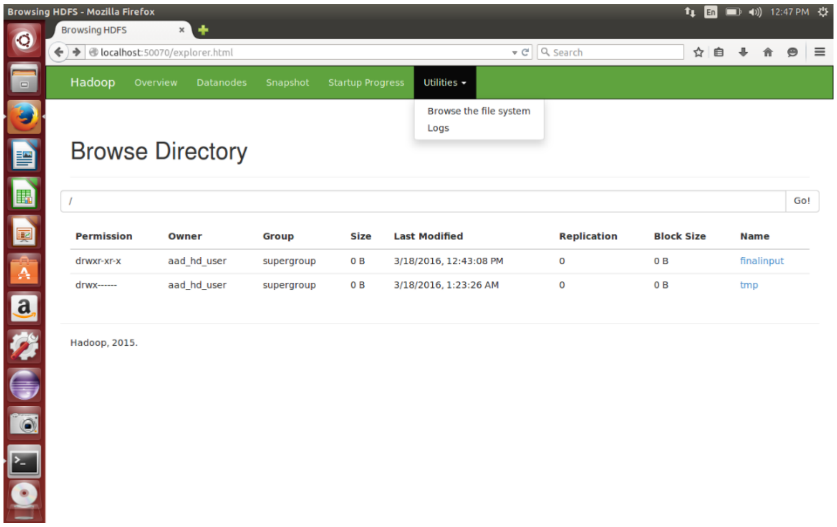
SSH setup is required to do different operations on a cluster such as starting, stopping, distributed daemon shell operations. To authenticate different users of Hadoop, it is required to provide public/private key pair for a Hadoop user and share it with different users.

We run a program on Hadoop from the already existing examples given.

Let's have an input directory where we will push a few files and our requirement is to count the total number of words in those files. To calculate the total number of words, we do not need to write our MapReduce, provided the .jar file contains the implementation for word count. You can try other examples using the same .jar file; just issue the following commands to check supported MapReduce functional programs by hadoop-mapreduce-examples-3.3.6.jar file.

Word-count Program execution in HDFS Environment

- When you have installed in Standalone mode, the data that you have used to run the program is from local file system.
- But now, in Pseudo Distributed mode, we will be seeing how to put the data into HDFS and get the data from HDFS, so that we will have the feeling of working on Hadoop(storage).

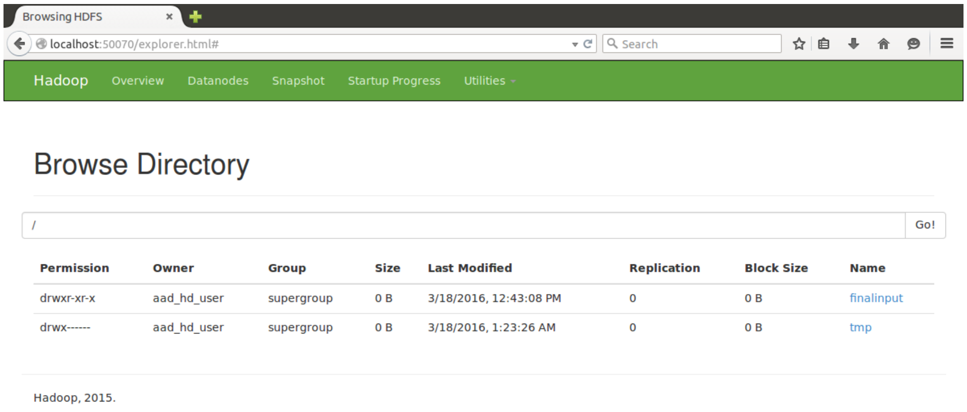


Browse Directory

/

Permission	Owner	Group	Size	Last Modified	Replication	Block Size	Name
drwxr-xr-x	aad_hd_user	supergroup	0 B	3/18/2016, 12:43:08 PM	0	0 B	finalinput
drwx------	aad_hd_user	supergroup	0 B	3/18/2016, 1:23:26 AM	0	0 B	tmp

Hadoop, 2015.



Browse Directory

/

Permission	Owner	Group	Size	Last Modified	Replication	Block Size	Name
drwxr-xr-x	aad_hd_user	supergroup	0 B	3/18/2016, 12:43:08 PM	0	0 B	finalinput
drwx------	aad_hd_user	supergroup	0 B	3/18/2016, 1:23:26 AM	0	0 B	tmp

Hadoop, 2015.

Now, use the following command to execute the program

Jar file name in the current directory

```
$ hadoop jar hadoop-mapreduce-examples-3.3.6.jar
wordcount hdfs://localhost:9000/mictinput hdfs://localhost:9000/mictoutput
```

This is keyword just like java

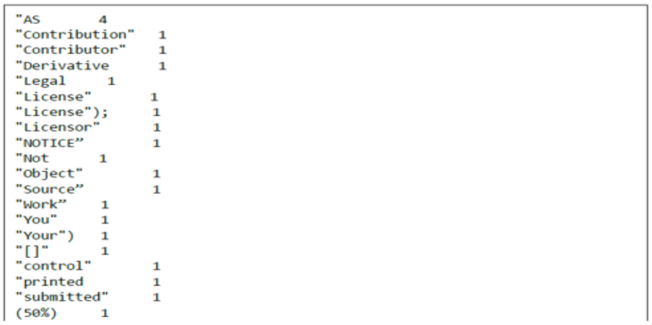
This is the file name

This is input directory

This is output directory

To see the output

```
$ hdfs dfs –cat hdfs://localhost:9000/mictoutput/part-r-00000
```



```
"AS       4
"Contribution"   1
"Contributor"    1
"Derivative      1
"Legal     1
"License"       1
"License");     1
"Licensor"      1
"NOTICE”        1
"Not      1
"Object"        1
"Source”        1
"Work”     1
"You"      1
"Your")    1
"[]"       1
"control"       1
"printed        1
"submitted"     1
(50%)      1
```

Instructions on Standalone mode:

Follow the steps given below to create a group and a user in that group:

```
$ clear
$ sudo addgroup  hadoopgroup
$ sudo adduser –ingroup hadoopgroup hadoopuser
```

To give permission to group

$sudo gedit /etc/sudoers - will open a file…in that…

Add the following line (after %sudo ALL=(ALL:ALL) ALL)
%hadoopgroup ALL=(ALL:ALL) ALL

Change the user form existing user… to hadoopuser

LOGOUT of the present user

LOGIN with the newly created user “hadoopuser”

After this, if you type pwd, we should get

$hadoopuser@ …….

1. sudo apt update

2. sudo apt install openjdk-8-jdk -y

3. java -version; javac -version

4. sudo apt install openssh-server openssh-client -y

5. sudo apt-get install vsftpd

6. ssh-keygen -t rsa -P '' -f ~/.ssh/id_rsa

7. cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys

8. chmod 0600 ~/.ssh/authorized_keys

9. ssh localhost

10. wgethttps://downloads.apache.org/hadoop/common/hadoop-3.3.6/hadoop-3.3.6.tar.gz

11. tar xzf hadoop-3.3.6.tar.gz

12. sudo nano .bashrc
paste

```
#Hadoop Related Options
export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64
export HADOOP_HOME=/home/hadoopuser/hadoop-3.3.4  - should be your username
export HADOOP_INSTALL=$HADOOP_HOME
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_HDFS_HOME=$HADOOP_HOME
export YARN_HOME=$HADOOP_HOME
export HADOOP_COMMON_LIB_NATIVE_DIR=$HADOOP_HOME/lib/native
export PATH=$PATH:$HADOOP_HOME/sbin:$HADOOP_HOME/bin
export HADOOP_OPTS="-Djava.library.path=$HADOOP_HOME/lib/native"
```

```
source ~/.bashrc
```

Just verify, whether everything is done properly or not , to check the path settings are reflected or not.

```
$ echo $JAVA_HOME
$ echo $HADOOP_HOME
$ echo $PATH
```

Now, Check whether Hadoop is working or not. (Just like Java -version)

```
$ hadoop version
```

As we are executing standard wordcount file in java...we have to copy that file to current directory

cp ./hadoop-3.3.6/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.3.6.jar . (after jar space dot represents current directory)

Leave one space here

This command copies the examples into present working directory i.e. your_user name

```
$ ls –lrt
```

Now, we will execute wordcount program.

For this, we need input directory, from which the input will be taken by the program. And output will be written to another directory.

So First create a directory named as input_dir and copy some text files into this directory.

```
$ mkdir input_dir
$ cp $HADOOP_HOME/*.txt input_dir
$ cd input_dir
$ ls –lrt
$ cd .. //to come to hadoopuser
```

Now, use the following command to execute the program

```
$ hadoop jar hadoop-mapreduce-examples-3.3.6.jar wordcount input_dir output_dir
```

or

```
$ mkdir input1
$ cp /home/hadoopuser/Downloads/example.txt input1
$ cd input_dir
$ ls –lrt
$ cd .. //to come to hadoopuser
```

Now, use the following command to execute the program

```
$ hadoop jar hadoop-mapreduce-examples-3.3.6 jar wordcount input1 output1
```

To see the output

```
$ cd output_dir
$ ls –lrt
$ cat part-r-00000
or
$ cd output1
$ ls –lrt
$ cat part-r-00000
```

Instructions on Pseudo Distributed mode:

Install OpenJDK on Ubuntu

The Hadoop framework is written in Java, and its services require a compatible Java Runtime Environment (JRE) and Java Development Kit (JDK). Use the following command to update your system before initiating a new installation:

```
sudo apt update
```

At the moment, **Apache Hadoop 3.x fully supports Java 8**. The OpenJDK 8 package in Ubuntu contains both the runtime environment and development kit.

Type the following command in your terminal to install OpenJDK 8:

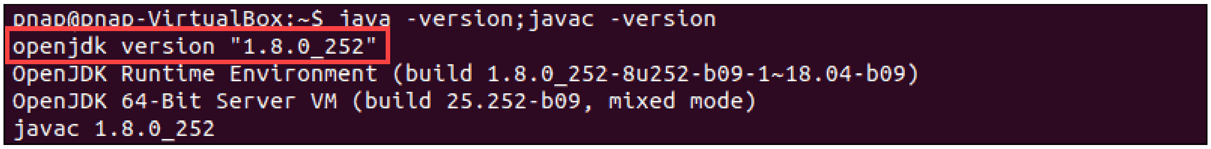
```
sudo apt install openjdk-8-jdk -y
```

The OpenJDK or Oracle Java version can affect how elements of a Hadoop ecosystem interact. To install a specific Java version, check out our detailed guide on how to install Java on Ubuntu.

Once the installation process is complete, verify the current Java version:

```
java -version; javac -version
```

The output informs you which Java edition is in use.



```
pnap@pnap-VirtualBox:~$ java -version;javac -version
openjdk version "1.8.0_252"
OpenJDK Runtime Environment (build 1.8.0_252-8u252-b09-1~18.04-b09)
OpenJDK 64-Bit Server VM (build 25.252-b09, mixed mode)
javac 1.8.0_252
```

Set Up a Non-Root User for Hadoop Environment

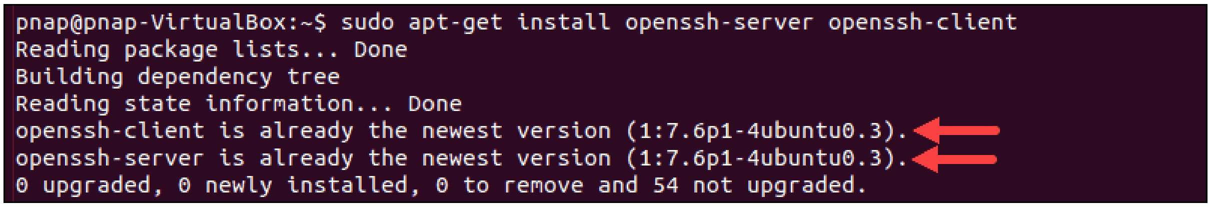
It is advisable to create a non-root user, specifically for the Hadoop environment. A distinct user improves security and helps you manage your cluster more efficiently. To ensure the smooth functioning of Hadoop services, the user should have the ability to establish a passwordless SSH connection with the localhost.

Install OpenSSH on Ubuntu

Install the OpenSSH server and client using the following command:

```
sudo apt install openssh-server openssh-client -y
sudo apt-get install vsftpd
```

In the example below, the output confirms that the latest version is already installed.



```
pnap@pnap-VirtualBox:~$ sudo apt-get install openssh-server openssh-client
Reading package lists... Done
Building dependency tree
Reading state information... Done
openssh-client is already the newest version (1:7.6p1-4ubuntu0.3).
openssh-server is already the newest version (1:7.6p1-4ubuntu0.3).
0 upgraded, 0 newly installed, 0 to remove and 54 not upgraded.
```

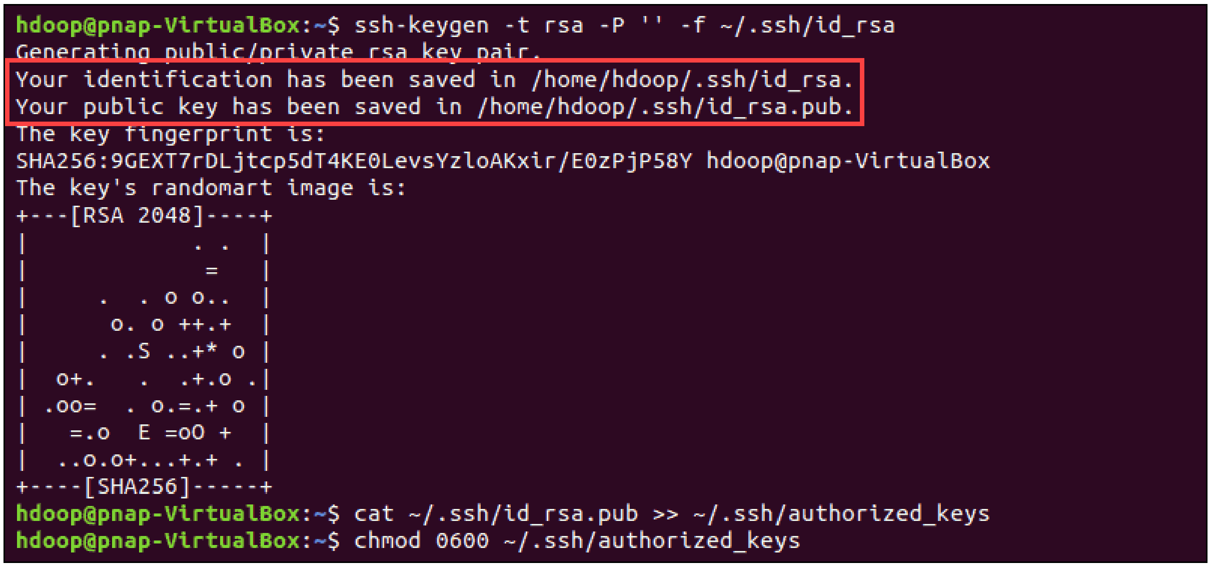
If you have installed OpenSSH for the first time, use this opportunity to implement these vital SSH security recommendations.

Enable Passwordless SSH for Hadoop User

Generate an SSH key pair and define the location is is to be stored in:

```
ssh-keygen -t rsa -P '' -f ~/.ssh/id_rsa
```

The system proceeds to generate and save the SSH key pair.



```
hdoop@pnap-VirtualBox:~$ ssh-keygen -t rsa -P '' -f ~/.ssh/id_rsa
Generating public/private rsa key pair.
Your identification has been saved in /home/hdoop/.ssh/id_rsa.
Your public key has been saved in /home/hdoop/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:9GEXT7rDLjtcp5dT4KE0LevsYzloAKxir/E0zPjP58Y hdoop@pnap-VirtualBox
The key's randomart image is:
+---[RSA 2048]----+
|            . .  |
|             =   |
|     .  . o o..  |
|      o. o ++.+  |
|     . .S ..+* o |
|  o+.   .  .+.o .|
| .oo=  . o.=.+ o |
|   =.o  E =oO +  |
|  ..o.o+...+.+ . |
+----[SHA256]-----+
hdoop@pnap-VirtualBox:~$ cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
hdoop@pnap-VirtualBox:~$ chmod 0600 ~/.ssh/authorized_keys
```

Use the `cat` command to store the public key as **authorized_keys** in the *ssh* directory:

```
cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
```

Set the permissions for your user with the `chmod` command:

```
chmod 0600 ~/.ssh/authorized_keys
```

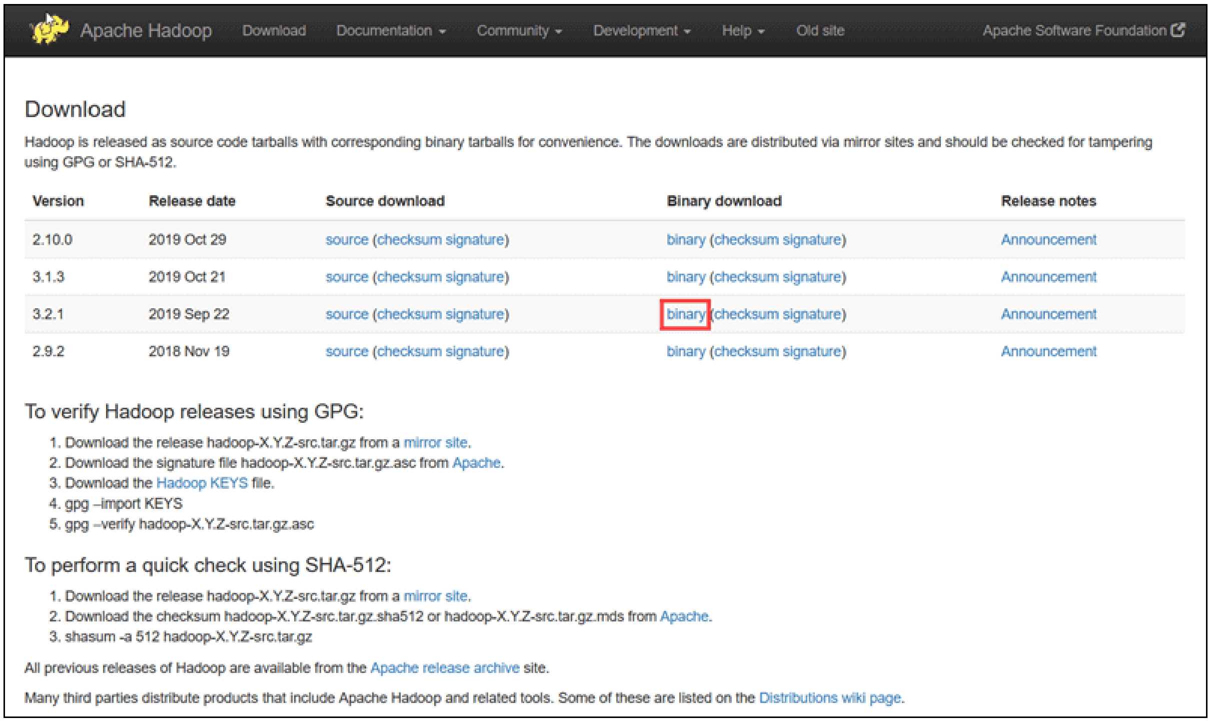
The new user is now able to SSH without needing to enter a password every time. Verify everything is set up correctly by using the **hdoop** user to SSH to localhost:

```
ssh localhost
```

After an initial prompt, the Hadoop user is now able to establish an SSH connection to the localhost seamlessly.

Download and Install Hadoop on Ubuntu

Visit the official Apache Hadoop project page, and select the version of Hadoop you want to implement.



Download

Hadoop is released as source code tarballs with corresponding binary tarballs for convenience. The downloads are distributed via mirror sites and should be checked for tampering using GPG or SHA-512.

Version	Release date	Source download	Binary download	Release notes
2.10.0	2019 Oct 29	source (checksum signature)	binary (checksum signature)	Announcement
3.1.3	2019 Oct 21	source (checksum signature)	binary (checksum signature)	Announcement
3.2.1	2019 Sep 22	source (checksum signature)	binary (checksum signature)	Announcement
2.9.2	2018 Nov 19	source (checksum signature)	binary (checksum signature)	Announcement

To verify Hadoop releases using GPG:

1. Download the release hadoop-X.Y.Z-src.tar.gz from a mirror site.
2. Download the signature file hadoop-X.Y.Z-src.tar.gz.asc from Apache.
3. Download the Hadoop KEYS file.
4. gpg –import KEYS
5. gpg –verify hadoop-X.Y.Z-src.tar.gz.asc

To perform a quick check using SHA-512:

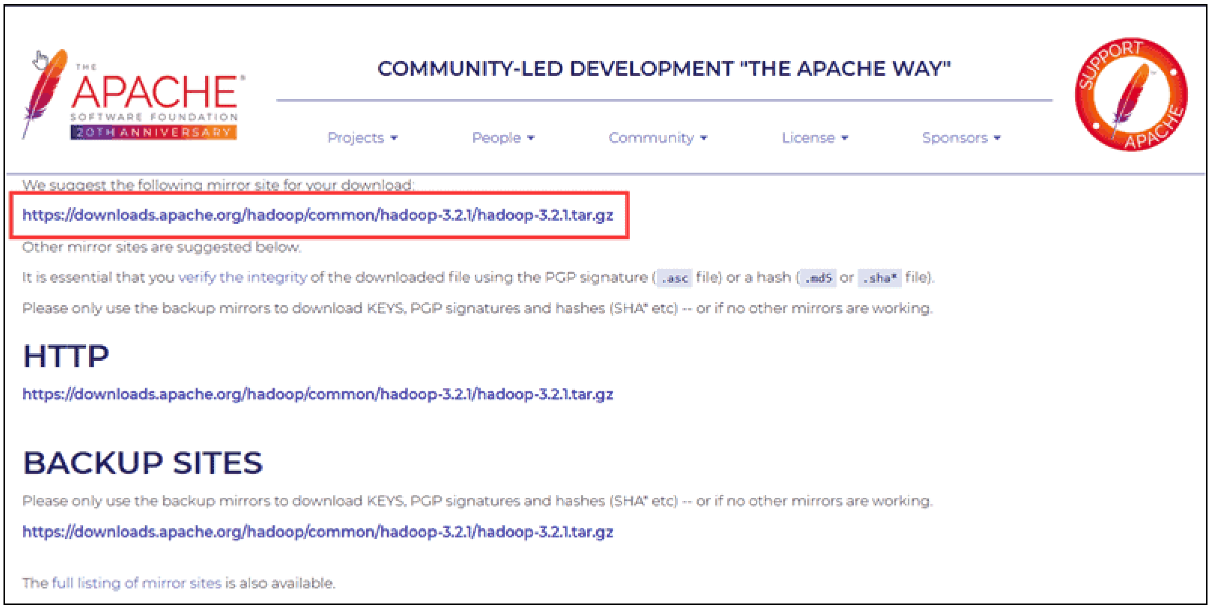
1. Download the release hadoop-X.Y.Z-src.tar.gz from a mirror site.
2. Download the checksum hadoop-X.Y.Z-src.tar.gz.sha512 or hadoop-X.Y.Z-src.tar.gz.mds from Apache.
3. shasum -a 512 hadoop-X.Y.Z-src.tar.gz

All previous releases of Hadoop are available from the Apache release archive site.

Many third parties distribute products that include Apache Hadoop and related tools. Some of these are listed on the Distributions wiki page.

The steps outlined in this tutorial use the Binary download for **Hadoop Version 3.3.6**.

Select your preferred option, and you are presented with a mirror link that allows you to download the **Hadoop tar package**.



We suggest the following mirror site for your download:

https://downloads.apache.org/hadoop/common/hadoop-3.2.1/hadoop-3.2.1.tar.gz

Other mirror sites are suggested below.

It is essential that you verify the integrity of the downloaded file using the PGP signature (`.asc` file) or a hash (`.md5` or `.sha*` file).

Please only use the backup mirrors to download KEYS, PGP signatures and hashes (SHA* etc) -- or if no other mirrors are working.

HTTP

https://downloads.apache.org/hadoop/common/hadoop-3.2.1/hadoop-3.2.1.tar.gz

BACKUP SITES

Please only use the backup mirrors to download KEYS, PGP signatures and hashes (SHA* etc) -- or if no other mirrors are working.

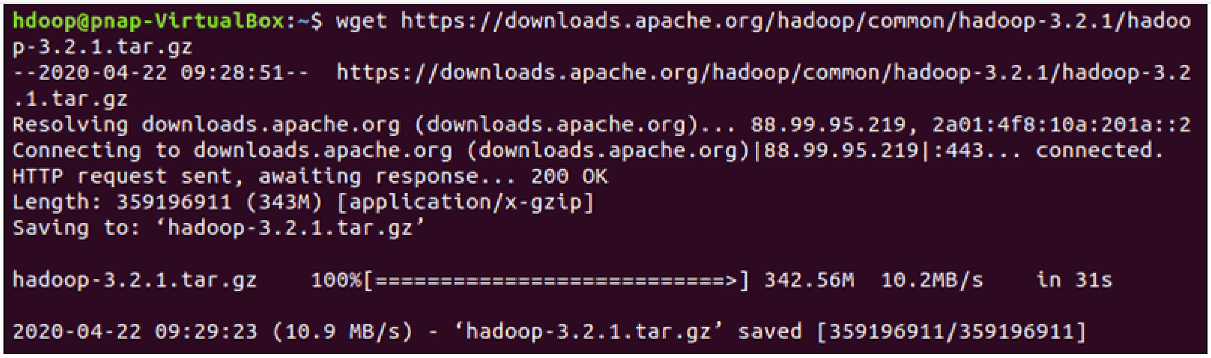
https://downloads.apache.org/hadoop/common/hadoop-3.2.1/hadoop-3.2.1.tar.gz

The full listing of mirror sites is also available.

Note: It is sound practice to verify Hadoop downloads originating from mirror sites. The instructions for using GPG or SHA-512 for verification are provided on the official download page.

Use the provided mirror link and download the Hadoop package with the `wget` command:

```
wget https://downloads.apache.org/hadoop/common/hadoop-3.3.6/hadoop-3.3.6.tar.gz
```



```
hdoop@pnap-VirtualBox:~$ wget https://downloads.apache.org/hadoop/common/hadoop-3.2.1/hadoo
p-3.2.1.tar.gz
--2020-04-22 09:28:51--  https://downloads.apache.org/hadoop/common/hadoop-3.2.1/hadoop-3.2
.1.tar.gz
Resolving downloads.apache.org (downloads.apache.org)... 88.99.95.219, 2a01:4f8:10a:201a::2
Connecting to downloads.apache.org (downloads.apache.org)|88.99.95.219|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 359196911 (343M) [application/x-gzip]
Saving to: ‘hadoop-3.2.1.tar.gz’

hadoop-3.2.1.tar.gz    100%[===========================>] 342.56M  10.2MB/s    in 31s

2020-04-22 09:29:23 (10.9 MB/s) - ‘hadoop-3.2.1.tar.gz’ saved [359196911/359196911]
```

Once the download is complete, extract the files to initiate the Hadoop installation:

```
tar xzf hadoop-3.3.6.tar.gz
```

The Hadoop binary files are now located within the *hadoop-3.3.6* directory.

Single Node Hadoop Deployment (Pseudo-Distributed Mode)

Hadoop excels when deployed in a **fully distributed mode** on a large cluster of networked servers. However, if you are new to Hadoop and want to explore basic commands or test applications, you can configure Hadoop on a single node.

This setup, also called **pseudo-distributed mode**, allows each Hadoop daemon to run as a single Java process. A Hadoop environment is configured by editing a set of configuration files:

- bashrc
- hadoop-env.sh
- core-site.xml
- hdfs-site.xml
- mapred-site-xml
- yarn-site.xml

Configure Hadoop Environment Variables (bashrc)

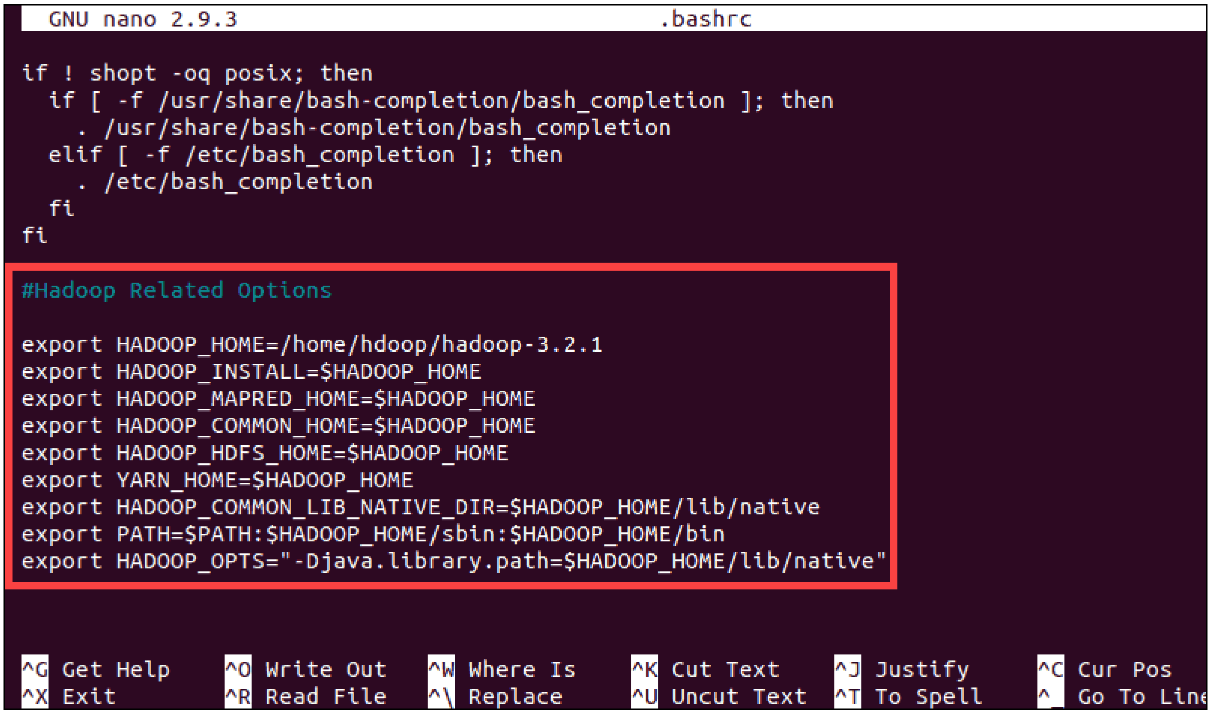
Edit the *.bashrc* shell configuration file using a text editor of your choice (we will be using nano):

```
sudo nano .bashrc
```

Define the Hadoop environment variables by adding the following content to the end of the file:

```
#Hadoop Related Options
export HADOOP_HOME=/home/hdoop/hadoop-3.3.6 – should be your user
export HADOOP_INSTALL=$HADOOP_HOME
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_HDFS_HOME=$HADOOP_HOME
export YARN_HOME=$HADOOP_HOME
export HADOOP_COMMON_LIB_NATIVE_DIR=$HADOOP_HOME/lib/native
export PATH=$PATH:$HADOOP_HOME/sbin:$HADOOP_HOME/bin
export HADOOP_OPTS="-Djava.library.path=$HADOOP_HOME/lib/native"
```

Once you add the variables, save and exit the *.bashrc* file.



```
if ! shopt -oq posix; then
  if [ -f /usr/share/bash-completion/bash_completion ]; then
    . /usr/share/bash-completion/bash_completion
  elif [ -f /etc/bash_completion ]; then
    . /etc/bash_completion
  fi
fi

#Hadoop Related Options

export HADOOP_HOME=/home/hdoop/hadoop-3.2.1
export HADOOP_INSTALL=$HADOOP_HOME
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_HDFS_HOME=$HADOOP_HOME
export YARN_HOME=$HADOOP_HOME
export HADOOP_COMMON_LIB_NATIVE_DIR=$HADOOP_HOME/lib/native
export PATH=$PATH:$HADOOP_HOME/sbin:$HADOOP_HOME/bin
export HADOOP_OPTS="-Djava.library.path=$HADOOP_HOME/lib/native"
```

It is vital to apply the changes to the current running environment by using the following command:

```
source ~/.bashrc
```

Edit hadoop-env.sh File

The *hadoop-env.sh* file serves as a master file to configure YARN, HDFS, MapReduce, and Hadoop-related project settings.

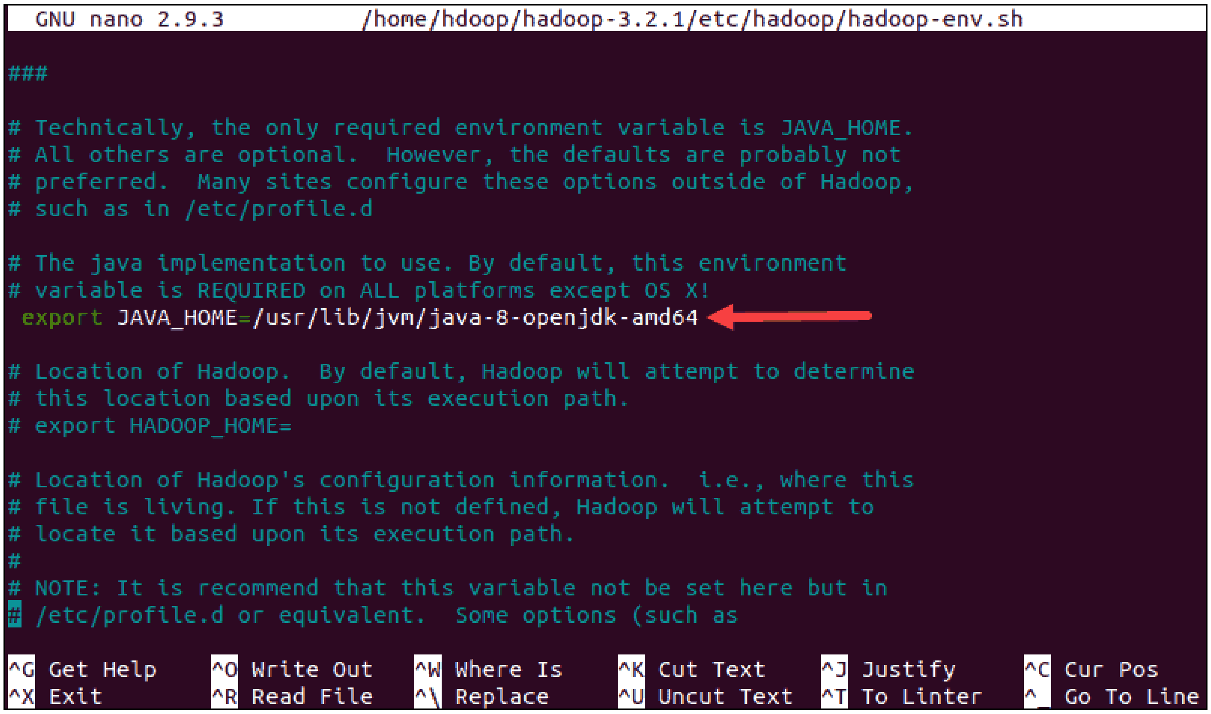
When setting up a **single node Hadoop cluster**, you need to define which Java implementation is to be utilized. Use the previously created `$HADOOP_HOME` variable to access the *hadoop-env.sh* file:

```
sudo nano $HADOOP_HOME/etc/hadoop/hadoop-env.sh
```

Uncomment the `$JAVA_HOME` variable (i.e., remove the `#` sign) and add the full path to the OpenJDK installation on your system. If you have installed the same version as presented in the first part of this tutorial, add the following line:

```
export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64
```

The path needs to match the location of the Java installation on your system.

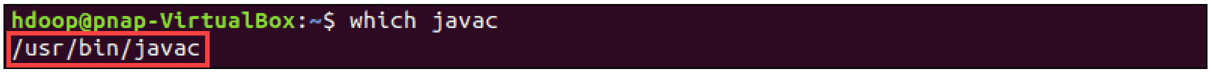


```
  GNU nano 2.9.3           /home/hdoop/hadoop-3.2.1/etc/hadoop/hadoop-env.sh

###

# Technically, the only required environment variable is JAVA_HOME.
# All others are optional.  However, the defaults are probably not
# preferred.  Many sites configure these options outside of Hadoop,
# such as in /etc/profile.d

# The java implementation to use. By default, this environment
# variable is REQUIRED on ALL platforms except OS X!
 export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64

# Location of Hadoop.  By default, Hadoop will attempt to determine
# this location based upon its execution path.
# export HADOOP_HOME=

# Location of Hadoop's configuration information.  i.e., where this
# file is living. If this is not defined, Hadoop will attempt to
# locate it based upon its execution path.
#
# NOTE: It is recommend that this variable not be set here but in
# /etc/profile.d or equivalent.  Some options (such as

^G Get Help   ^O Write Out  ^W Where Is   ^K Cut Text   ^J Justify    ^C Cur Pos
^X Exit       ^R Read File  ^\ Replace    ^U Uncut Text ^T To Linter  ^_ Go To Line
```

If you need help to locate the correct Java path, run the following command in your terminal window:

```
which javac
```

The resulting output provides the path to the Java binary directory.

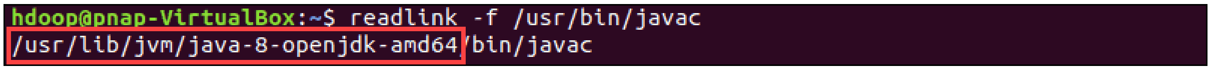


```
hdoop@pnap-VirtualBox:~$ which javac
/usr/bin/javac
```

Use the provided path to find the OpenJDK directory with the following command:

```
readlink -f /usr/bin/javac
```

The section of the path just before the */bin/javac* directory needs to be assigned to the `$JAVA_HOME` variable.



```
hdoop@pnap-VirtualBox:~$ readlink -f /usr/bin/javac
/usr/lib/jvm/java-8-openjdk-amd64/bin/javac
```

Edit core-site.xml File

The *core-site.xml* file defines HDFS and Hadoop core properties.

To set up Hadoop in a pseudo-distributed mode, you need to **specify the URL** for your NameNode, and the temporary directory Hadoop uses for the map and reduce process.

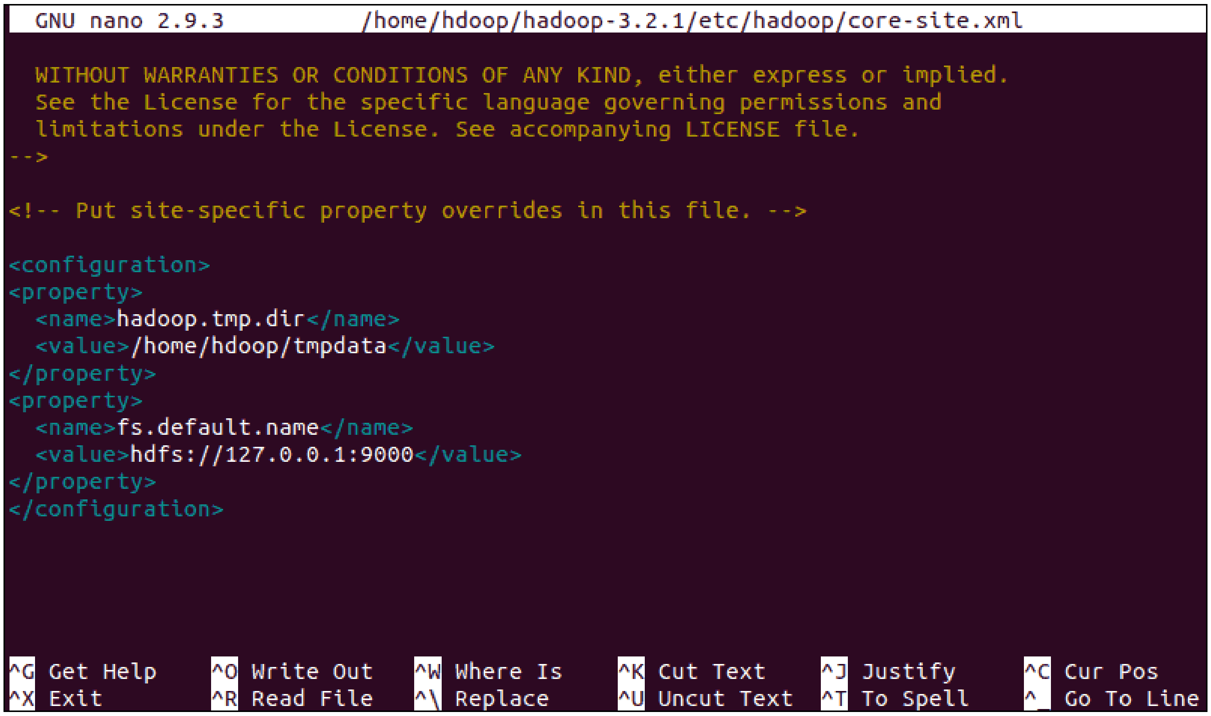
Open the *core-site.xml* file in a text editor:

```
sudo nano $HADOOP_HOME/etc/hadoop/core-site.xml
```

Add the following configuration to override the default values for the temporary directory and add your HDFS URL to replace the default local file system setting:

```
<configuration>
<property>
  <name>hadoop.tmp.dir</name>
  <value>/home/hdoop/tmpdata</value> should be your user
</property>
<property>
  <name>fs.default.name</name>
  <value>hdfs://127.0.0.1:9000</value>
</property>
</configuration>
```

This example uses values specific to the local system. You should use values that match your systems requirements. The data needs to be consistent throughout the configuration process.



```
  GNU nano 2.9.3           /home/hdoop/hadoop-3.2.1/etc/hadoop/core-site.xml

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  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
<property>
  <name>hadoop.tmp.dir</name>
  <value>/home/hdoop/tmpdata</value>
</property>
<property>
  <name>fs.default.name</name>
  <value>hdfs://127.0.0.1:9000</value>
</property>
</configuration>
```

Do not forget to create a Linux directory in the location you specified for your temporary data.

Edit hdfs-site.xml File

The properties in the *hdfs-site.xml* file govern the location for storing node metadata, fsimage file, and edit log file. Configure the file by defining the **NameNode** and **DataNode storage directories**.

Additionally, the default `dfs.replication` value of `3` needs to be changed to `1` to match the single node setup.

Use the following command to open the *hdfs-site.xml* file for editing:

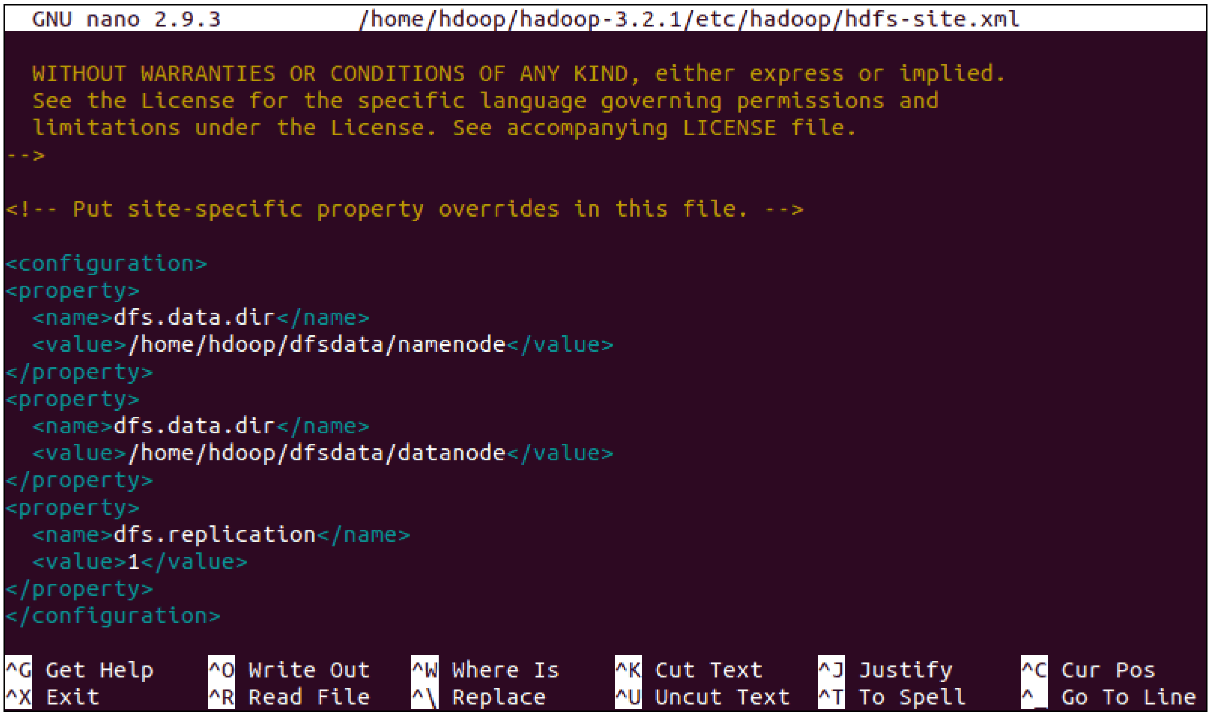
```
sudo nano $HADOOP_HOME/etc/hadoop/hdfs-site.xml
```

Add the following configuration to the file and, if needed, adjust the NameNode and DataNode directories to your custom locations:

```
<configuration>
<property>
  <name>dfs.data.dir</name>
  <value>/home/hdoop/dfsdata/namenode</value> should be your user
</property>
<property>
  <name>dfs.data.dir</name>
  <value>/home/hdoop/dfsdata/datanode</value>  should be your user
```

```
</property>
<property>
  <name>dfs.replication</name>
  <value>1</value>
</property>
</configuration>
```

If necessary, create the specific directories you defined for the `dfs.data.dir` value.



```
  GNU nano 2.9.3          /home/hdoop/hadoop-3.2.1/etc/hadoop/hdfs-site.xml

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  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
<property>
  <name>dfs.data.dir</name>
  <value>/home/hdoop/dfsdata/namenode</value>
</property>
<property>
  <name>dfs.data.dir</name>
  <value>/home/hdoop/dfsdata/datanode</value>
</property>
<property>
  <name>dfs.replication</name>
  <value>1</value>
</property>
</configuration>

^G Get Help    ^O Write Out   ^W Where Is    ^K Cut Text    ^J Justify     ^C Cur Pos
^X Exit        ^R Read File   ^\ Replace     ^U Uncut Text  ^T To Spell    ^_ Go To Line
```

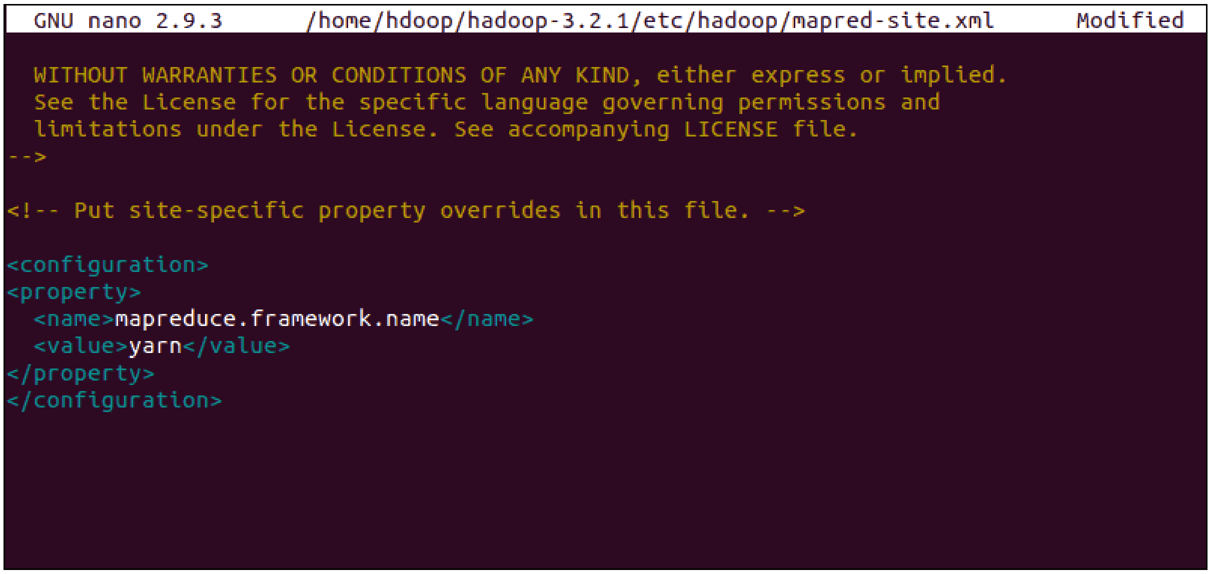
Edit mapred-site.xml File

Use the following command to access the *mapred-site.xml* file and **define MapReduce values**:

```
sudo nano $HADOOP_HOME/etc/hadoop/mapred-site.xml
```

Add the following configuration to change the default MapReduce framework name value to `yarn`:

```
<configuration>
<property>
  <name>mapreduce.framework.name</name>
  <value>yarn</value>
</property>
</configuration>
```



```
  GNU nano 2.9.3        /home/hdoop/hadoop-3.2.1/etc/hadoop/mapred-site.xml        Modified

  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
<property>
  <name>mapreduce.framework.name</name>
  <value>yarn</value>
</property>
</configuration>
```

Edit yarn-site.xml File

The *yarn-site.xml* file is used to define settings relevant to **YARN**. It contains configurations for the **Node Manager, Resource Manager, Containers,** and **Application Master**.

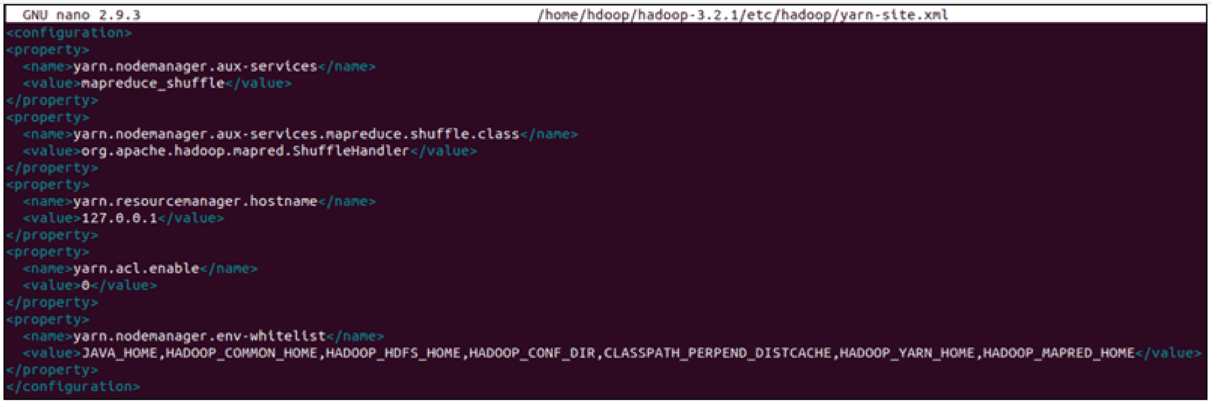
Open the *yarn-site.xml* file in a text editor:

```
sudo nano $HADOOP_HOME/etc/hadoop/yarn-site.xml
```

Append the following configuration to the file:

```
<configuration>
<property>
  <name>yarn.nodemanager.aux-services</name>
  <value>mapreduce_shuffle</value>
</property>
<property>
  <name>yarn.nodemanager.aux-services.mapreduce.shuffle.class</name>
  <value>org.apache.hadoop.mapred.ShuffleHandler</value>
</property>
<property>
  <name>yarn.resourcemanager.hostname</name>
  <value>127.0.0.1</value>
</property>
<property>
  <name>yarn.acl.enable</name>
  <value>0</value>
</property>
<property>
  <name>yarn.nodemanager.env-whitelist</name>
```

```
<value>JAVA_HOME,HADOOP_COMMON_HOME,HADOOP_HDFS_HOME,HADOOP_CONF_DIR,CLASSPATH_PERPEND_DISTCACHE,HADOOP_YARN_HOME,HADOOP_MAPRED_HOME</value>
</property>
</configuration>
```



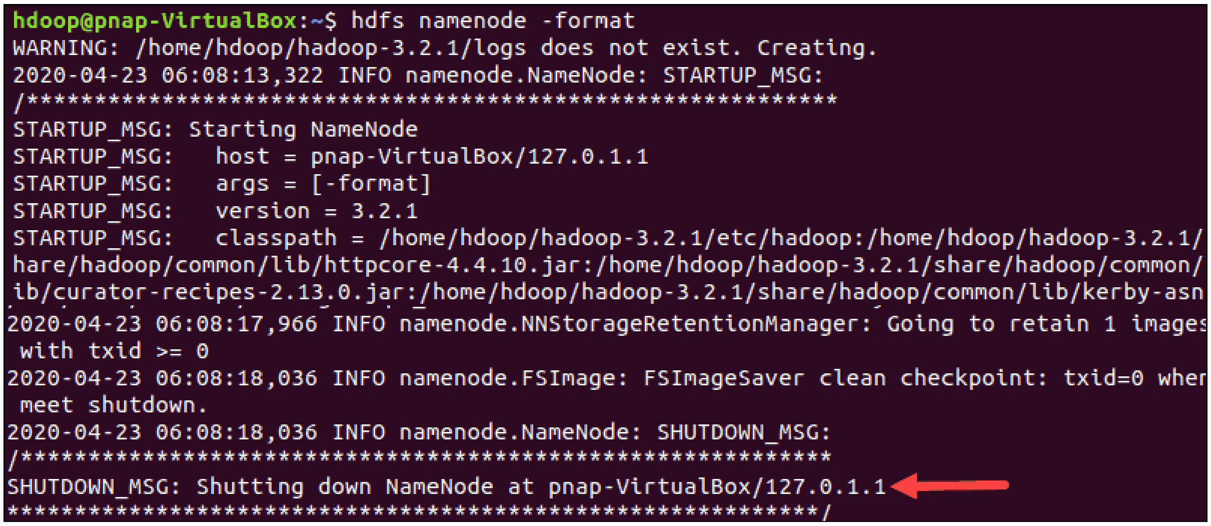
```
  GNU nano 2.9.3                                   /home/hdoop/hadoop-3.2.1/etc/hadoop/yarn-site.xml
<configuration>
<property>
  <name>yarn.nodemanager.aux-services</name>
  <value>mapreduce_shuffle</value>
</property>
<property>
  <name>yarn.nodemanager.aux-services.mapreduce.shuffle.class</name>
  <value>org.apache.hadoop.mapred.ShuffleHandler</value>
</property>
<property>
  <name>yarn.resourcemanager.hostname</name>
  <value>127.0.0.1</value>
</property>
<property>
  <name>yarn.acl.enable</name>
  <value>0</value>
</property>
<property>
  <name>yarn.nodemanager.env-whitelist</name>
  <value>JAVA_HOME,HADOOP_COMMON_HOME,HADOOP_HDFS_HOME,HADOOP_CONF_DIR,CLASSPATH_PERPEND_DISTCACHE,HADOOP_YARN_HOME,HADOOP_MAPRED_HOME</value>
</property>
</configuration>
```

Format HDFS NameNode

It is important to **format the NameNode** before starting Hadoop services for the first time:

```
hdfs namenode -format
```

The shutdown notification signifies the end of the NameNode format process.



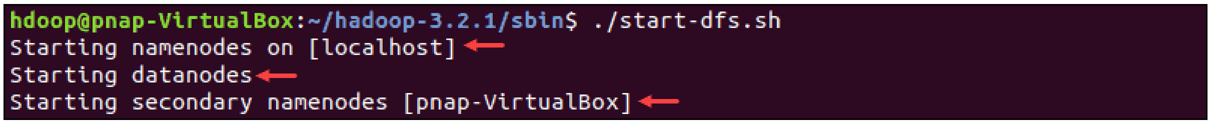
```
hdoop@pnap-VirtualBox:~$ hdfs namenode -format
WARNING: /home/hdoop/hadoop-3.2.1/logs does not exist. Creating.
2020-04-23 06:08:13,322 INFO namenode.NameNode: STARTUP_MSG:
/************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = pnap-VirtualBox/127.0.1.1
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 3.2.1
STARTUP_MSG:   classpath = /home/hdoop/hadoop-3.2.1/etc/hadoop:/home/hdoop/hadoop-3.2.1/
hare/hadoop/common/lib/httpcore-4.4.10.jar:/home/hdoop/hadoop-3.2.1/share/hadoop/common/
ib/curator-recipes-2.13.0.jar:/home/hdoop/hadoop-3.2.1/share/hadoop/common/lib/kerby-asn
2020-04-23 06:08:17,966 INFO namenode.NNStorageRetentionManager: Going to retain 1 images
 with txid >= 0
2020-04-23 06:08:18,036 INFO namenode.FSImage: FSImageSaver clean checkpoint: txid=0 wher
 meet shutdown.
2020-04-23 06:08:18,036 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at pnap-VirtualBox/127.0.1.1
************************************************************/
```

Start Hadoop Cluster

Navigate to the *hadoop-3.3.4/sbin* directory and execute the following commands to start the NameNode and DataNode:

```
./start-dfs.sh
```

The system takes a few moments to initiate the necessary nodes.

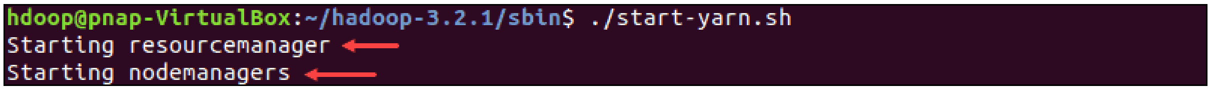


```
hdoop@pnap-VirtualBox:~/hadoop-3.2.1/sbin$ ./start-dfs.sh
Starting namenodes on [localhost]
Starting datanodes
Starting secondary namenodes [pnap-VirtualBox]
```

Once the namenode, datanodes, and secondary namenode are up and running, start the YARN resource and nodemanagers by typing:

```
./start-yarn.sh
```

As with the previous command, the output informs you that the processes are starting.

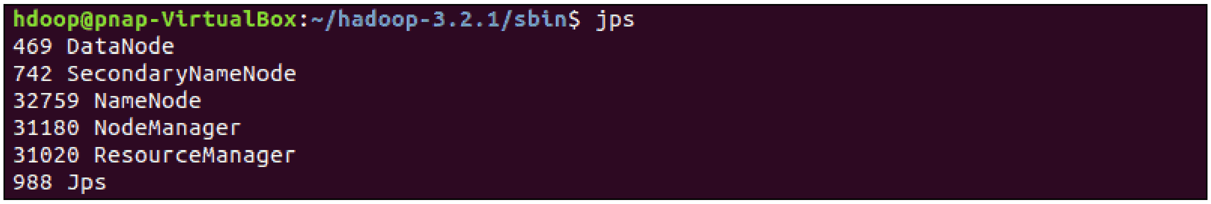


```
hdoop@pnap-VirtualBox:~/hadoop-3.2.1/sbin$ ./start-yarn.sh
Starting resourcemanager
Starting nodemanagers
```

Type this simple command to check if all the daemons are active and running as Java processes:

```
jps
```

If everything is working as intended, the resulting list of running Java processes contains all the HDFS and YARN daemons.



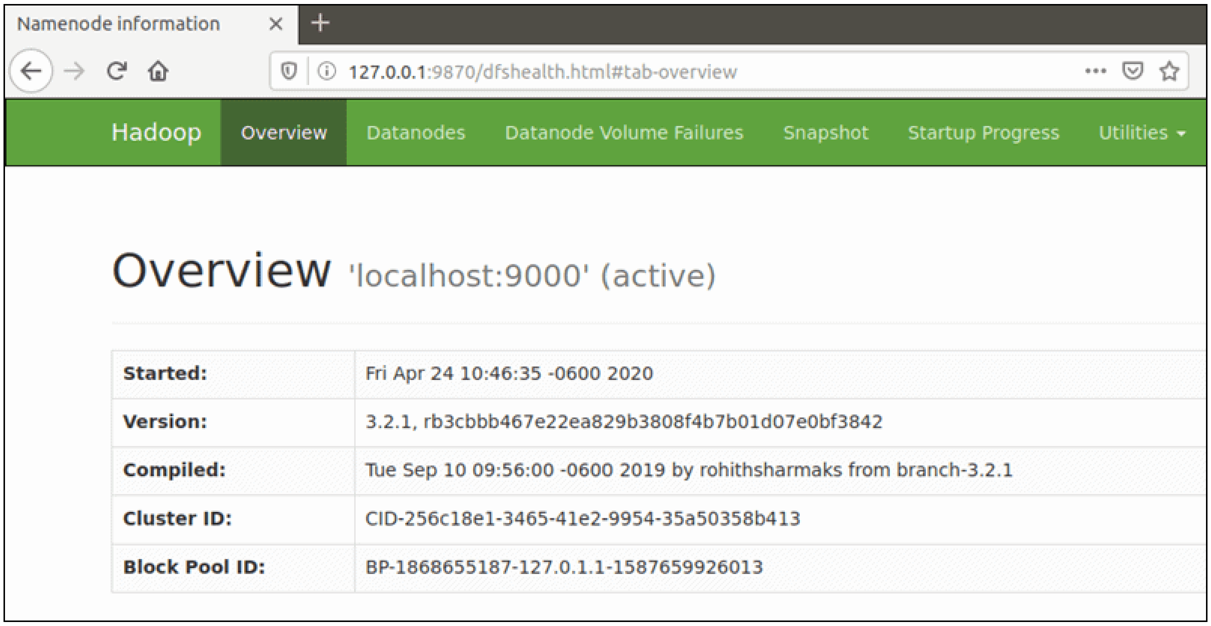
```
hdoop@pnap-VirtualBox:~/hadoop-3.2.1/sbin$ jps
469 DataNode
742 SecondaryNameNode
32759 NameNode
31180 NodeManager
31020 ResourceManager
988 Jps
```

Access Hadoop UI from Browser

Use your preferred browser and navigate to your localhost URL or IP. The default port number **9870** gives you access to the Hadoop NameNode UI:

```
http://localhost:9870
```

The NameNode user interface provides a comprehensive overview of the entire cluster.

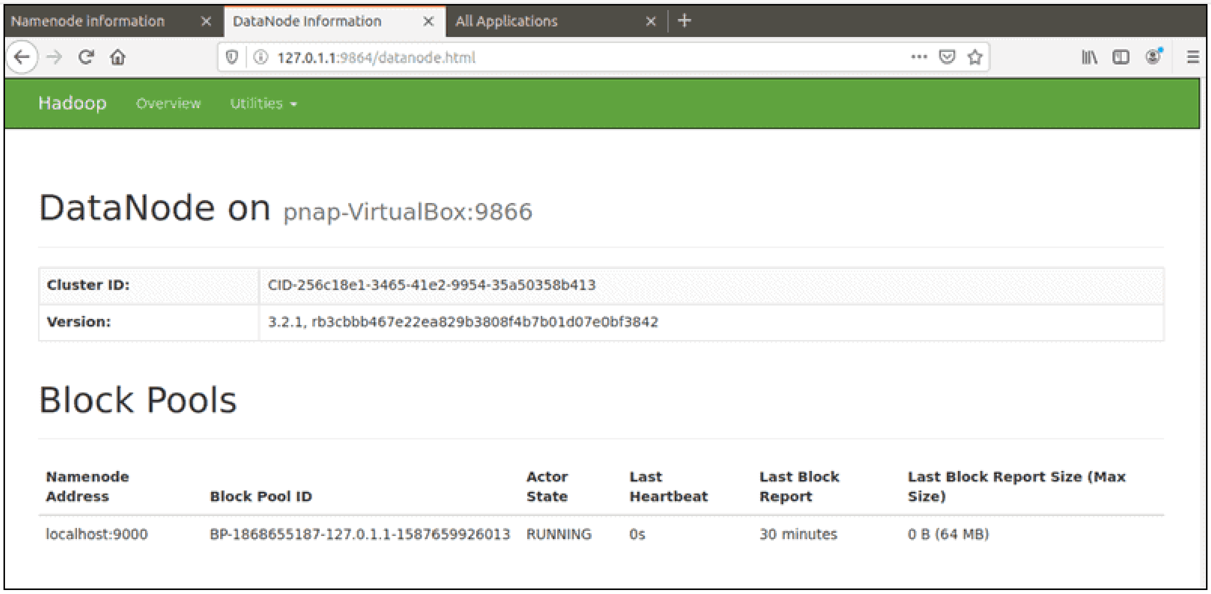


Overview 'localhost:9000' (active)

Started:	Fri Apr 24 10:46:35 -0600 2020
Version:	3.2.1, rb3cbbb467e22ea829b3808f4b7b01d07e0bf3842
Compiled:	Tue Sep 10 09:56:00 -0600 2019 by rohithsharmaks from branch-3.2.1
Cluster ID:	CID-256c18e1-3465-41e2-9954-35a50358b413
Block Pool ID:	BP-1868655187-127.0.1.1-1587659926013

The default port **9864** is used to access individual DataNodes directly from your browser:

```
http://localhost:9864
```



DataNode on pnap-VirtualBox:9866

Cluster ID:	CID-256c18e1-3465-41e2-9954-35a50358b413
Version:	3.2.1, rb3cbbb467e22ea829b3808f4b7b01d07e0bf3842

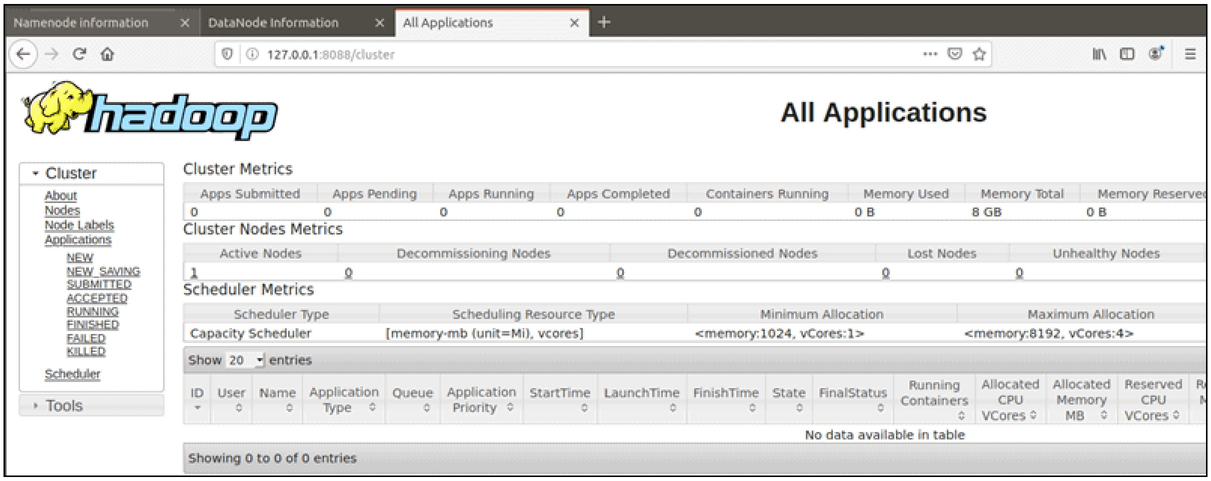
Block Pools

Namenode Address	Block Pool ID	Actor State	Last Heartbeat	Last Block Report	Last Block Report Size (Max Size)
localhost:9000	BP-1868655187-127.0.1.1-1587659926013	RUNNING	0s	30 minutes	0 B (64 MB)

The YARN Resource Manager is accessible on port **8088**:

```
http://localhost:8088
```

The Resource Manager is an invaluable tool that allows you to monitor all running processes in your Hadoop cluster.



All Applications

Cluster Metrics

Apps Submitted	Apps Pending	Apps Running	Apps Completed	Containers Running	Memory Used	Memory Total	Memory Reserved
0	0	0	0	0	0 B	8 GB	0 B

Cluster Nodes Metrics

Active Nodes	Decommissioning Nodes	Decommissioned Nodes	Lost Nodes	Unhealthy Nodes
1	0	0	0	0

Scheduler Metrics

Scheduler Type	Scheduling Resource Type	Minimum Allocation	Maximum Allocation
Capacity Scheduler	[memory-mb (unit=Mi), vcores]	<memory:1024, vCores:1>	<memory:8192, vCores:4>

Show 20 entries

ID	User	Name	Application Type	Queue	Application Priority	StartTime	LaunchTime	FinishTime	State	FinalStatus	Running Containers	Allocated CPU VCores	Allocated Memory MB	Reserved CPU VCores	R M
No data available in table															

Showing 0 to 0 of 0 entries

Conclusion

You have successfully installed Hadoop on Ubuntu and deployed it in a pseudo-distributed mode. A single node Hadoop deployment is an excellent starting point to explore basic HDFS commands and acquire the experience you need to design a fully distributed Hadoop cluster

Finally all nodes should be stopped...so use command

./stop-all.sh

Hadoop Streaming using Python:

Hadoop Streaming is a feature that comes with Hadoop and allows users or developers to use various languages for writing MapReduce programs like Python, C++, Ruby, etc. It supports all the languages that can read from standard input and write to standard output. We will be implementing Python with Hadoop Streaming and will observe how it works. We will implement the word count problem in python to understand Hadoop Streaming. We will be creating ***mapper.py*** and ***reducer.py*** to perform map and reduce tasks.

Follow the instructions:

1. write mapper.py and reducer.py

```
chmod 777 mapper.py reducer.py
```

2. Make input directories:

```
hdfs dfs -mkdir /dir1
hdfs dfs -mkdir /dir1/input
```

3. hdfs put into input directory hadoop file system:

```
hdfs dfs -put examples.txt /dir1/input/
```

```
hadoop jar ../hadoop-3.3.6/share/hadoop/tools/lib/hadoop-streaming-3.3.6.jar -file mapper.py -mapper mapper.py -file  reducer.py -reducer  reducer.py -input /dir1/input/* -output /dir1/output
```

4.Remove already created output directory to run again or create new output directory:

```
hdfs dfs -rm -r /dir1/output
```

Reference:

1. https://www.michael-noll.com/tutorials/running-hadoop-on-ubuntu-linux-single-node-cluster/
2. https://www.youtube.com/watch?v=QNB1SZm2jS4
3. https://www.edureka.co/blog/install-hadoop-single-node-hadoop-cluster

LAB – 11 & LAB – 12

Working on Mini Project

Topics related to Distributed Systems