MultiThreading:

- in multithreading we create multiple threads and execute them n a single processor(we have to wait for one program to complete for other thread to start)
- In **context switching** we don't have to wait for thread 1 to finish executing for other one to start. it will execute some part of thread1 then execute some of thread2 and so on.

MultiProcessing:

- in multiprocessing we run multiple instances of a program parallely in different processord
- i.e for program 1 in processor 1, program2 in processor 2, program3 in processor 3, program 4 in processor 4 and so on.
- Advantages of using multiprocessing:-
    - for 4 core processor program will be executed in 1/4 amount of time
    - latency of progr5am will be reduced
    - multiple instances can be run in an easiest possible way
    - Any shared resources b/w two processors can be utilised

In [10]:

```
import multiprocessing
def multipross():
    print("This is my mutiprocessing prog")

#to execute above program with some other program-
#call a python mai program-which is responsible for executing everything inside our pytho
if __name__=="__main__": #this __main__ envokes our entire python compileri.e python main
    m= multiprocessing.Process(target=multipross)
    print("this is my main program")
    #above creates a child program inside a main program

    #starting program
    m.start()
    m.join() #waits until child process terminates
```

```
this is my main program
This is my mutiprocessing prog
```

In [ ]:

Q) Create a function for squaring a number. distribute this into 5 processes using pool function:

In [12]:

```
def do_sqr(n):
    return(n**2)

#creating child Program
if __name__=='__main__':
    with multiprocessing.Pool(10)as pool:
        out=pool.map(do_sqr,[2,4,65,5,8,9,9])
        print(out)
```

```
[4, 16, 4225, 25, 64, 81, 81]
```

In [ ]:

In [ ]:

Resource:- https://www.geeksforgeeks.org/multiprocessing-python-set-1/ (https://www.geeksforgeeks.org/multiprocessing-python-set-1/)

Multiprocessing in Python

What is multiprocessing?

Multiprocessing refers to the ability of a system to support more than one processor at the same time

In [13]:

```
# importing the multiprocessing module
import multiprocessing

def print_cube(num):
    """
    function to print cube of given num
    """
    print("Cube: {}".format(num * num * num))

def print_square(num):
    """
    function to print square of given num
    """
    print("Square: {}".format(num * num))

if __name__ == "__main__":
    # creating processes
    p1 = multiprocessing.Process(target=print_square, args=(10, ))
    p2 = multiprocessing.Process(target=print_cube, args=(10, ))

    # starting process 1
    p1.start()
    # starting process 2
    p2.start()


    # wait until process 1 is finished
    p1.join()
    # wait until process 2 is finished
    p2.join()

    # both processes finished
    print("Done!")
```

```
Square: 100
Cube: 1000
Done!
```

In [14]:

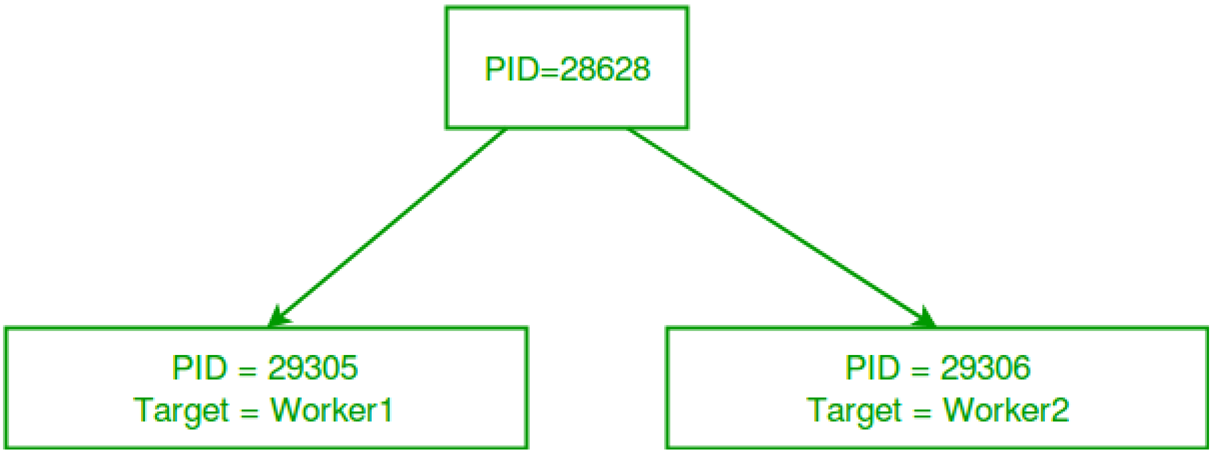
```
#example:  program to understand the concept of different processes running on same pytho
# importing the multiprocessing module
import multiprocessing
import os

def worker1():
    # printing process id
    print("ID of process running worker1: {}".format(os.getpid()))

def worker2():
    # printing process id
    print("ID of process running worker2: {}".format(os.getpid()))

if __name__ == "__main__":
    # printing main program process id
    print("ID of main process: {}".format(os.getpid()))

    # creating processes
    p1 = multiprocessing.Process(target=worker1)
    p2 = multiprocessing.Process(target=worker2)

    # starting processes
    p1.start()
    p2.start()

    # process IDs
    print("ID of process p1: {}".format(p1.pid))
    print("ID of process p2: {}".format(p2.pid))

    # wait until processes are finished
    p1.join()
    p2.join()

    # both processes finished
    print("Both processes finished execution!")

    # check if processes are alive
    print("Process p1 is alive: {}".format(p1.is_alive()))
    print("Process p2 is alive: {}".format(p2.is_alive()))
```

```
ID of main process: 103
ID of process running worker1: 2486
ID of process running worker2: 2489
ID of process p1: 2486
ID of process p2: 2489
Both processes finished execution!
Process p1 is alive: False
Process p2 is alive: False
```

In [ ]:

In [ ]:

Consider the diagram to understand how new processes are different from main python script:



In [ ]:

In [ ]:

In [20]:

```
l=[1,2,3,4]
a = list(enumerate(l))
print(a)
```

```
[(0, 1), (1, 2), (2, 3), (3, 4)]
```

In [2]:

```
import multiprocessing

def square_list(mylist, result, square_sum):
    """
    function to square a given list
    """
    # append squares of mylist to result array
    for idx, num in enumerate(mylist):
        result[idx] = num * num

    # square_sum value
    square_sum.value = sum(result)

    # print result Array
    print("Result(in process p1): {}".format(result[:]))

    # print square_sum Value
    print("Sum of squares(in process p1): {}".format(square_sum.value))

if __name__ == "__main__":
    # input list
    mylist = [1,2,3,4]

    # creating Array of int data type with space for 4 integers
    result = multiprocessing.Array('i', 4)

    # creating Value of int data type
    square_sum = multiprocessing.Value('i')

    # creating new process
    p1 = multiprocessing.Process(target=square_list, args=(mylist, result, square_sum))

    # starting process
    p1.start()

    # wait until the process is finished
    p1.join()

    # print result array
    print("Result(in main program): {}".format(result[:]))

    # print square_sum Value
    print("Sum of squares(in main program): {}".format(square_sum.value))
```

```
Result(in process p1): [1, 4, 9, 16]
Sum of squares(in process p1): 30
Result(in main program): [1, 4, 9, 16]
Sum of squares(in main program): 30
```

Let us try to understand the above code line by line:

- First of all, we create an Array result like this: result = multiprocessing.Array('i', 4)
    - First argument is the data type. ‘i’ stands for integer whereas ‘d’ stands for float data type.
    - Second argument is the size of array. Here, we create an array of 4 elements.

Similarly, we create a Value square_sum like this:

- square_sum = multiprocessing.Value('i')

Here, we only need to specify data type. The value can be given an initial value(say 10) like this:

- square_sum = multiprocessing.Value('i', 10)

- Secondly, we pass result and square_sum as arguments while creating Process object.
  - p1 = multiprocessing.Process(target=square_list, args=(mylist, result, square_sum))
- result array elements are given a value by specifying index of array element.
  - for idx, num in enumerate(mylist): result[idx] = num * num

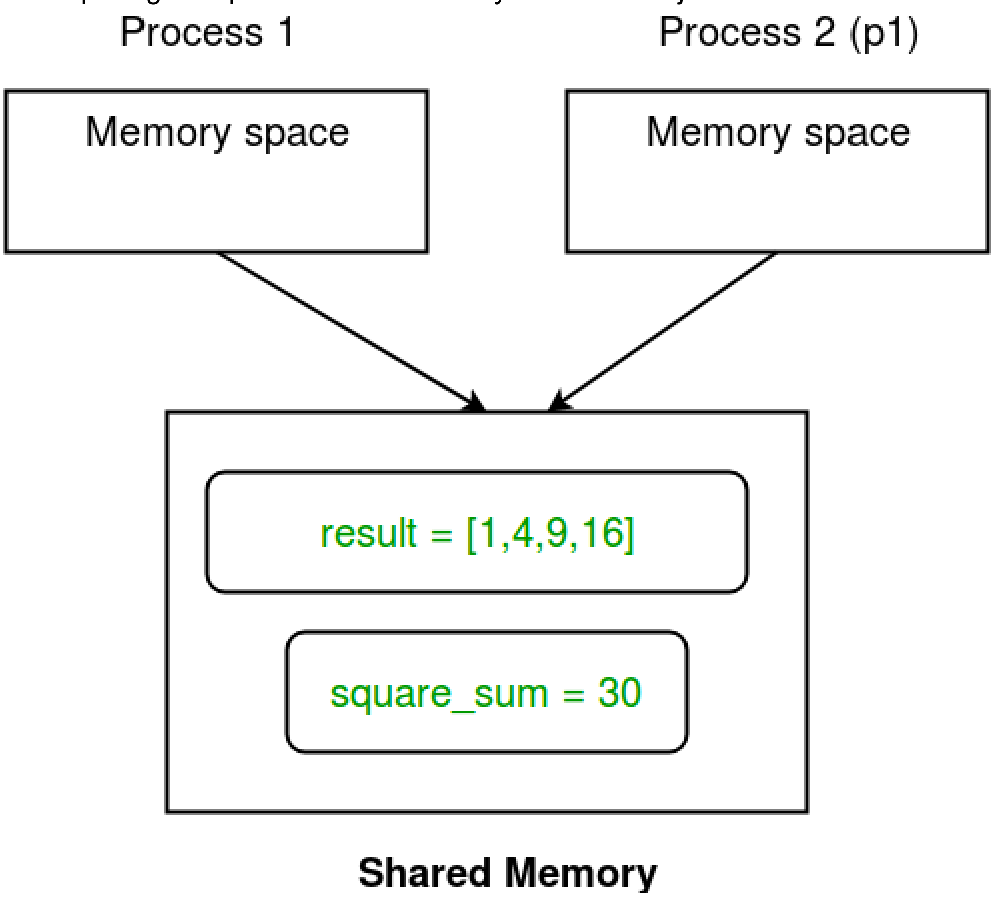
    square_sum is given a value by using its value attribute:

    square_sum.value = sum(result)
- In order to print result array elements, we use result[:] to print complete array. print("Result(in process p1): {}".format(result[:]))

  Value of square_sum is simply printed as:

  ```
  print("Sum of squares(in process p1): {}".format(square_sum.value))
  ```

Here is a diagram depicting how processes share Array and Value object:



In [ ]:

Server process :

In [6]:

```
import multiprocessing

def print_records(records):
    """
    function to print record(tuples) in records(list)
    """
    for record in records:
        print("Name: {0}\nScore: {1}\n".format(record[0], record[1]))

def insert_record(record, records):
    """
    function to add a new record to records(list)
    """
    records.append(record)
    print("New record added!\n")

if __name__ == '__main__':
    with multiprocessing.Manager() as manager:
        # creating a list in server process memory
        records = manager.list([('Sam', 10), ('Adam', 9), ('Kevin',9)])
        # new record to be inserted in records
        new_record = ('Jeff', 8)

        # creating new processes
        p1 = multiprocessing.Process(target=insert_record, args=(new_record, records))
        p2 = multiprocessing.Process(target=print_records, args=(records,))

        # running process p1 to insert new record
        p1.start()
        p1.join()

        # running process p2 to print records
        p2.start()
        p2.join()
```

```
New record added!

Name: Sam
Score: 10

Name: Adam
Score: 9

Name: Kevin
Score: 9

Name: Jeff
Score: 8
```

Let us try to understand above piece of code:

- First of all, we create a **manager** object using:

  ```
  with multiprocessing.Manager() as manager:
  ```

  All the lines under **with** statement block are under the scope of **manager** object.

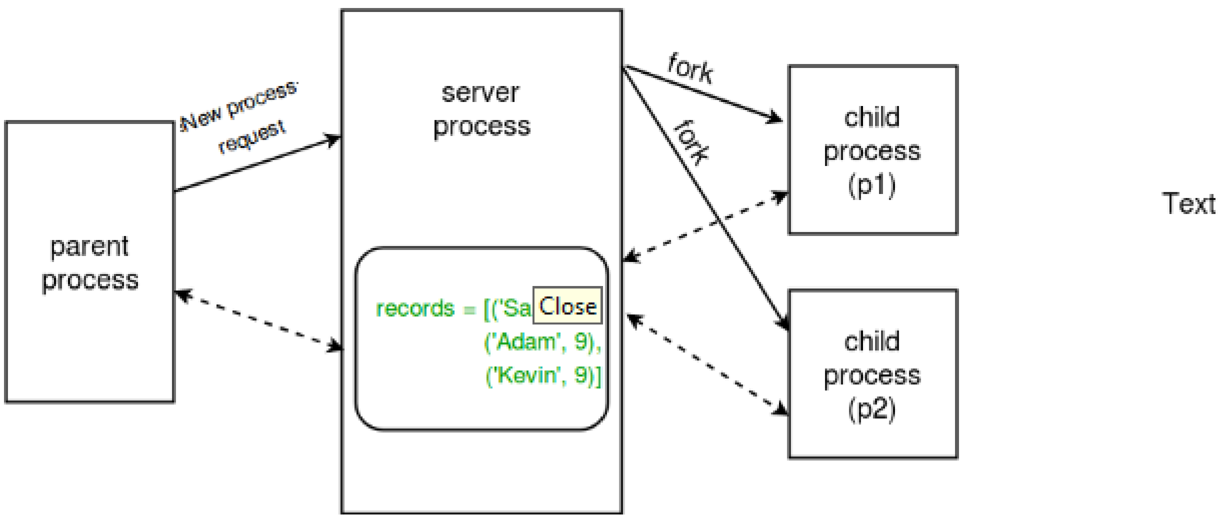
- Then, we create a list **records** in **server process** memory using:

  ```
  records = manager.list([('Sam', 10), ('Adam', 9), ('Kevin',9)])
  ```

  Similarly, you can create a dictionary as **manager.dict** method.

- Finally, we create to processes **p1** (to insert a new record in **records** list) and **p2** (to print **records**) and run them while passing **records** as one of the arguments.

The concept of **server process** is depicted in the diagram shown below:



Communication between processes

Communication between processes

Effective use of multiple processes usually requires some communication between them, so that work can be divided and results can be aggregated.
multiprocessing supports two types of communication channel between processes:

- Queue
- Pipe

1. **Queue :** A simple way to communicate between process with multiprocessing is to use a Queue to pass messages back and forth. Any Python object can pass through a Queue.
   Note: The **multiprocessing.Queue** class is a near clone of **queue.Queue**.

In [7]:

```
import multiprocessing

def square_list(mylist, q):
    """
    function to square a given list
    """
    # append squares of mylist to queue
    for num in mylist:
        q.put(num * num)

def print_queue(q):
    """
    function to print queue elements
    """
    print("Queue elements:")
    while not q.empty():
        print(q.get())
    print("Queue is now empty!")

if __name__ == "__main__":
    # input list
    mylist = [1,2,3,4]

    # creating multiprocessing Queue
    q = multiprocessing.Queue()

    # creating new processes
    p1 = multiprocessing.Process(target=square_list, args=(mylist, q))
    p2 = multiprocessing.Process(target=print_queue, args=(q,))

    # running process p1 to square list
    p1.start()
    p1.join()

    # running process p2 to get queue elements
    p2.start()
    p2.join()
```

```
Queue elements:
1
4
9
16
Queue is now empty!
```

Let us try to understand the above code step by step:

- Firstly, we create a **multiprocessing Queue** using:

```
q = multiprocessing.Queue()
```

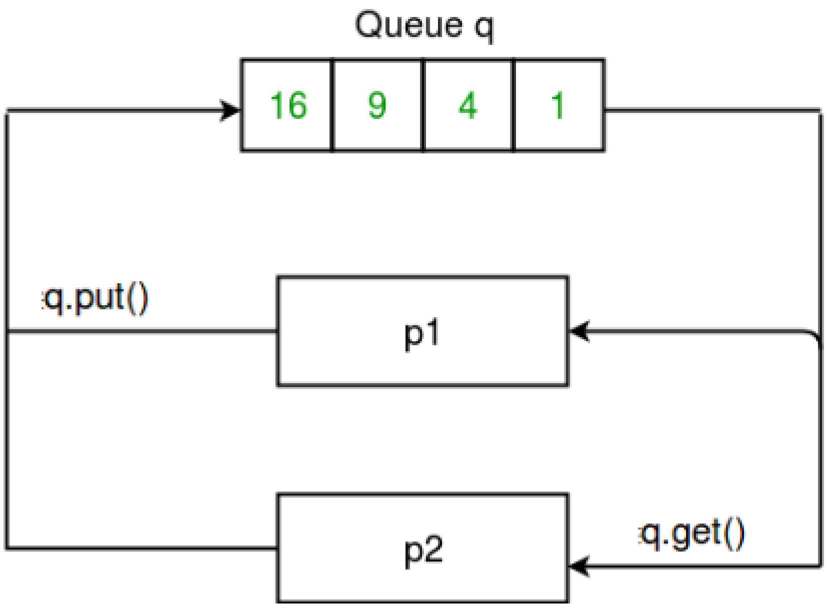
- Then we pass empty queue **q** to **square_list** function through process **p1**. Elements are inserted to queue using **put** method.

```
q.put(num * num)
```

- In order to print queue elements, we use **get** method until queue is not empty.

```
while not q.empty():
    print(q.get())
```

Given below is a simple diagram depicting the operations on queue:



2. **Pipes :** A pipe can have only two endpoints. Hence, it is preferred over queue when only two-way communication is required.
   multiprocessing module provides **Pipe()** function which returns a pair of connection objects connected by a pipe. The two connection objects returned by **Pipe()** represent the two ends of the pipe. Each connection object has **send()** and **recv()** methods (among others).
   Consider the program given below:

In [8]:

```python
import multiprocessing

def sender(conn, msgs):
    """
    function to send messages to other end of pipe
    """
    for msg in msgs:
        conn.send(msg)
        print("Sent the message: {}".format(msg))
    conn.close()

def receiver(conn):
    """
    function to print the messages received from other
    end of pipe
    """
    while 1:
        msg = conn.recv()
        if msg == "END":
            break
        print("Received the message: {}".format(msg))

if __name__ == "__main__":
    # messages to be sent
    msgs = ["hello", "hey", "hru?", "END"]

    # creating a pipe
    parent_conn, child_conn = multiprocessing.Pipe()

    # creating new processes
    p1 = multiprocessing.Process(target=sender, args=(parent_conn,msgs))
    p2 = multiprocessing.Process(target=receiver, args=(child_conn,))

    # running processes
    p1.start()
    p2.start()

    # wait until processes finish
    p1.join()
    p2.join()
```

```
Sent the message: hello
Sent the message: heyReceived the message: hello

Sent the message: hru?Received the message: hey

Sent the message: ENDReceived the message: hru?
```

Let us try to understand above code:

- A pipe was created simply using:

```
parent_conn, child_conn = multiprocessing.Pipe()
```

  The function returned two connection objects for the two ends of the pipe.

- Message is sent from one end of pipe to another using **send** method.

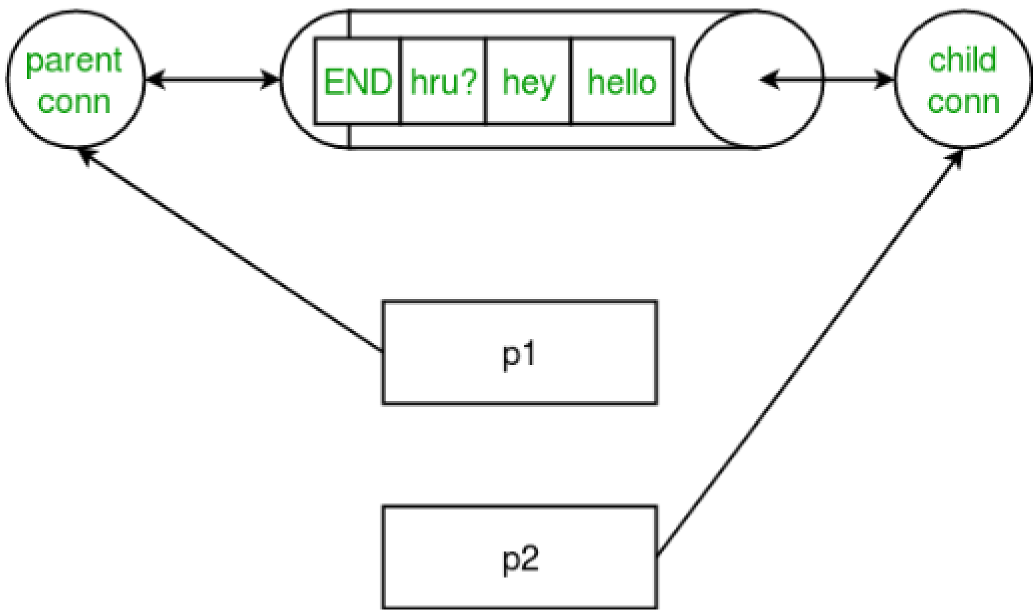
```
conn.send(msg)
```

- To receive any messages at one end of a pipe, we use **recv** method.

```
msg = conn.recv()
```

- In above program, we send a list of messages from one end to another. At the other end, we read messages until we receive “END” message.

Consider the diagram given below which shows the relation b/w pipe and processes:



Note: Data in a pipe may become corrupted if two processes (or threads) try to read from or write to the same end of the pipe at the same time. Of course, there is no risk of corruption from processes using different ends of the pipe at the same time. Also note that Queues do proper synchronization between processes, at the expense of more complexity. Hence, queues are said to be thread and process safe!

In [ ]:

```

```

Synchronization and Pooling of processes in Python

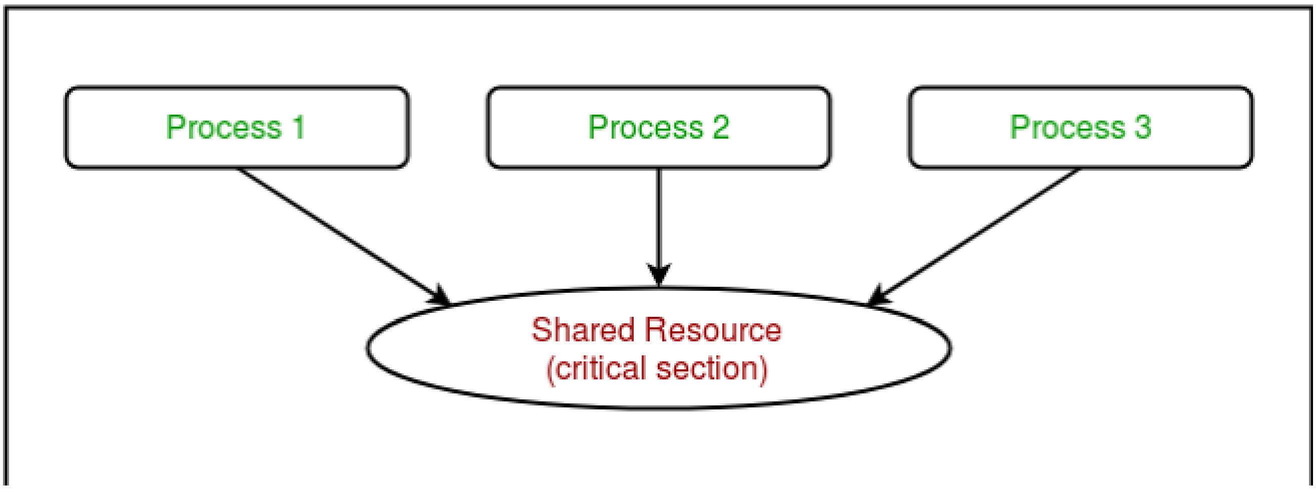
This article discusses two important concepts related to multiprocessing in Python:

- Synchronization between processes
- Pooling of processes

Synchronization between processes

Process synchronization is defined as a mechanism which ensures that two or more concurrent processes do not simultaneously execute some particular program segment known as critical section

For example, in the diagram below, 3 processes try to access shared resource or critical section at the same time.



Concurrent accesses to shared resource can lead to race condition.

> A race condition occurs when two or more processes can access shared data and they try to change it at the same time. As a result, the values of variables may be unpredictable and vary depending on the timings of context switches of the processes.

In [19]:

```
# Python program to illustrate
# the concept of race condition
# in multiprocessing
import multiprocessing

# function to withdraw from account
def withdraw(balance):
    for _ in range(10000):
        balance.value = balance.value - 1

# function to deposit to account
def deposit(balance):
    for _ in range(10000):
        balance.value = balance.value + 1

def perform_transactions():

    # initial balance (in shared memory)
    balance = multiprocessing.Value('i', 100)

    # creating new processes
    p1 = multiprocessing.Process(target=withdraw, args=(balance,))
    p2 = multiprocessing.Process(target=deposit, args=(balance,))

    # starting processes
    p1.start()
    p2.start()

    # wait until processes are finished
    p1.join()
    p2.join()

    # print final balance
    print("Final balance = {}".format(balance.value))

if __name__ == "__main__":
    for _ in range(10):

        # perform same transaction process 10 times
        perform_transactions()
```

```
Final balance = 803
Final balance = -479
Final balance = 231
Final balance = 582
Final balance = 439
Final balance = -133
Final balance = -300
Final balance = 399
Final balance = -293
Final balance = 297
```

In above program, 10000 withdraw and 10000 deposit transactions are carried out with initial balance as 100. The expected final balance is 100 but what we get in 10 iterations of **perform_transactions** function is some different values.

This happens due to concurrent access of processes to the shared data **balance**. This unpredictability in balance value is nothing but **race condition**.

Let us try to understand it better using the sequence diagrams given below. These are the different sequences which can be produced in above example for a single withdraw and deposit action.

- This is a possible sequence which gives wrong answer as both processes read the same value and write it back accordingly.

- This is a possible sequence which gives wrong answer as both processes read the same value and write it back accordingly.

p1	p2	balance
read(balance) current=100		100
	read(balance) current=100	100
balance=current-1=99 **write(balance)**		99
	balance=current+1=101 **write(balance)**	101

- These are 2 possible sequences which are desired in above scenario.

p1	p2	balance
read(balance) current=100		100
balance=current-1=99 **write(balance)**		99
	read(balance) current=99	99
	balance=current+1=100 **write(balance)**	100

p1	p2	balance
	read(balance) current=100	100
	balance=current+1=101 **write(balance)**	101
read(balance) current=101		101
balance=current-1=100 **write(balance)**		100

multiprocessing module provides a **Lock** class to deal with the race conditions. **Lock** is implemented using a **Semaphore** object provided by the Operating System.

> *A semaphore is a synchronization object that controls access by multiple processes to a common resource in a parallel programming environment. It is simply a value in a designated place in operating system (or kernel) storage that each process can check and then change. Depending on the value that is found, the process can use the resource or will find that it is already in use and must wait for some period before trying again. Semaphores can be binary (0 or 1) or can have additional values. Typically, a process using semaphores checks the value and then, if it using the resource, changes the value to reflect this so that subsequent semaphore users will know to wait.*

In [20]:

```
# Python program to illustrate
# the concept of locks
# in multiprocessing
import multiprocessing

# function to withdraw from account
def withdraw(balance, lock):
    for _ in range(10000):
        lock.acquire()
        balance.value = balance.value - 1
        lock.release()

# function to deposit to account
def deposit(balance, lock):
    for _ in range(10000):
        lock.acquire()
        balance.value = balance.value + 1
        lock.release()

def perform_transactions():

    # initial balance (in shared memory)
    balance = multiprocessing.Value('i', 100)

    # creating a lock object
    lock = multiprocessing.Lock()

    # creating new processes
    p1 = multiprocessing.Process(target=withdraw, args=(balance,lock))
    p2 = multiprocessing.Process(target=deposit, args=(balance,lock))

    # starting processes
    p1.start()
    p2.start()

    # wait until processes are finished
    p1.join()
    p2.join()

    # print final balance
    print("Final balance = {}".format(balance.value))

if __name__ == "__main__":
    for _ in range(10):

        # perform same transaction process 10 times
        perform_transactions()
```

```
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
Final balance = 100
```

Let us try to understand the above code step by step:

- Firstly, a **Lock** object is created using:

```
lock = multiprocessing.Lock()
```

- Then, **lock** is passed as target function argument:

```
 p1 = multiprocessing.Process(target=withdraw, args=
(balance,lock))
 p2 = multiprocessing.Process(target=deposit, args=
(balance,lock))
```

- In the critical section of target function, we apply lock using **lock.acquire()** method. As soon as a lock is acquired, no other process can access its critical section until the lock is released using **lock.release()** method.

```
lock.acquire()
balance.value = balance.value - 1
lock.release()
```

As you can see in the results, the final balance comes out to be 100 every time (which is the expected final result).

In [ ]:

```

```

In [ ]:

```

```

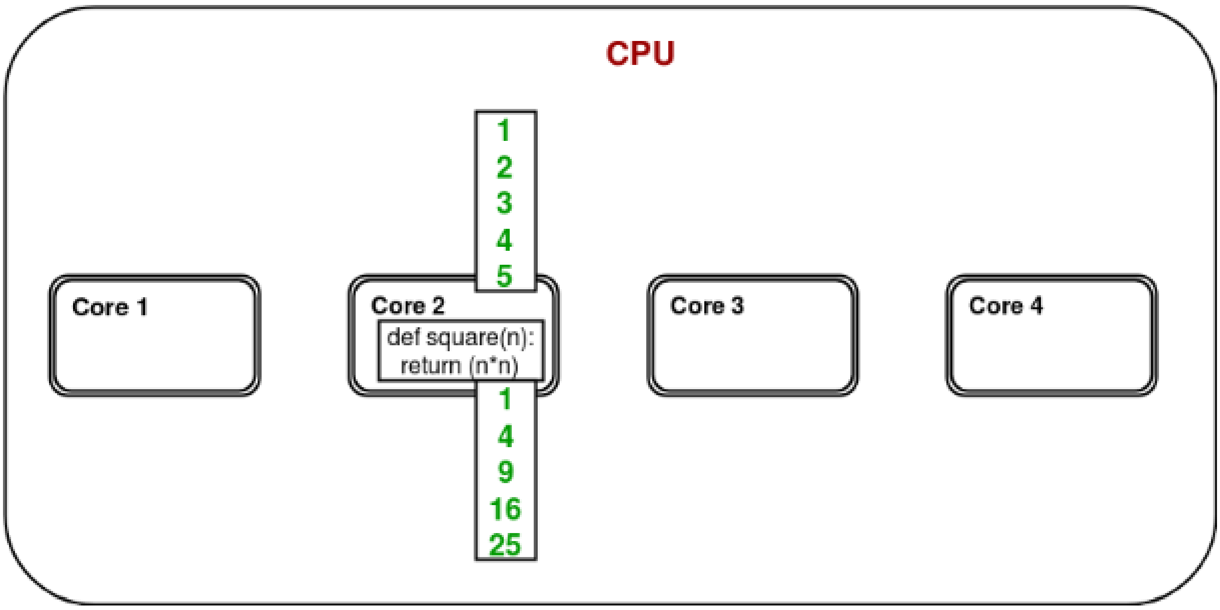
Pooling between processes

In [21]:

```
# Python program to find
# squares of numbers in a given list
def square(n):
    return (n*n)

if __name__ == "__main__":

    # input list
    mylist = [1,2,3,4,5]

    # empty list to store result
    result = []

    for num in mylist:
        result.append(square(num))

    print(result)
```

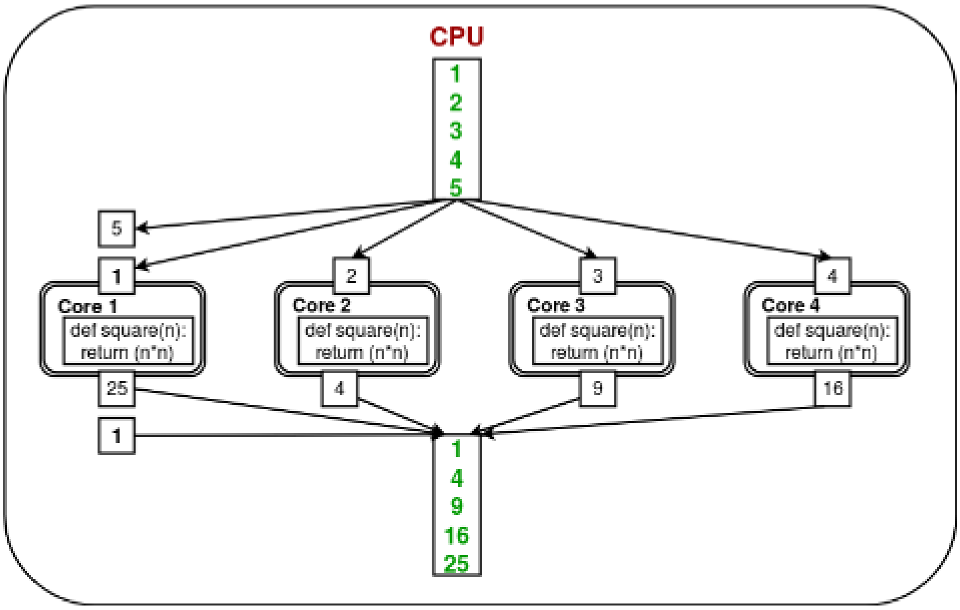
```
[1, 4, 9, 16, 25]
```

It is a simple program to calculate squares of elements of a given list. In a multi-core/multi-processor system, consider the diagram below to understand how above program will work:



Only one of the cores is used for program execution and it's quite possible that other cores remain idle.

In order to utilize all the cores, **multiprocessing** module provides a **Pool** class. The **Pool** class represents a pool of worker processes. It has methods which allows tasks to be offloaded to the worker processes in a few different ways. Consider the diagram below:



Here, the task is offloaded/distributed among the cores/processes automatically by **Pool** object. User doesn't need to worry about creating processes explicitly.

In [23]:

```
# Python program to understand
# the concept of pool
import multiprocessing
import os

def square(n):
    print("Worker process id for {0}: {1}".format(n, os.getpid()))
    return (n*n)

if __name__ == "__main__":
    # input list
    mylist = [1,2,3,4,5]

    # creating a pool object
    p = multiprocessing.Pool()

    # map list to target function
    result = p.map(square, mylist)

    print(result)
```

```
Worker process id for 1: 3168Worker process id for 2: 3169Worker process i
d for 3: 3170


Worker process id for 4: 3171Worker process id for 5: 3172

[1, 4, 9, 16, 25]
```

In [ ]: