Implimentation:

This is the final code I have implemented for solving the problem of sudoku using backtracking
As we have done till so far there are three sub-segments of code

Graph.py:

```
class Node :

    def __init__(self, idx, data = 0) : # Constructor
        self.id = idx
        self.data = data
        self.connectedTo = dict()

    def addNeighbour(self, neighbour , weight = 0) :
        if neighbour.id not in self.connectedTo.keys() :
            self.connectedTo[neighbour.id] = weight

    # setter
    def setData(self, data) :
        self.data = data

    #getter
    def getConnections(self) :
        return self.connectedTo.keys()

    def getID(self) :
        return self.id

    def getData(self) :
        return self.data

    def getWeight(self, neighbour) :
        return self.connectedTo[neighbour.id]

    def __str__(self) :
        return str(self.data) + " Connected to : "+ \
         str([x.data for x in self.connectedTo])

class Graph :
    totalV = 0 # total vertices in the graph
    def __init__(self) :
```

```
    self.allNodes = dict()
def addNode(self, idx) :
    if idx in self.allNodes :
        return None
    Graph.totalV += 1
    node = Node(idx=idx)
    self.allNodes[idx] = node
    return node

def addNodeData(self, idx, data) :
    if idx in self.allNodes :
        node = self.allNodes[idx]
        node.setData(data)
    else :
        print("No ID to add the data.")

def addEdge(self, src, dst, wt = 0) :
    self.allNodes[src].addNeighbour(self.allNodes[dst], wt)
    self.allNodes[dst].addNeighbour(self.allNodes[src], wt)

def isNeighbour(self, u, v) :
    if u >=1 and u <= 81 and v >=1 and v<= 81 and u !=v :
        if v in self.allNodes[u].getConnections() :
            return True
    return False



def printEdges(self) :
    for idx in self.allNodes :
        node =  self.allNodes[idx]
        for con in node.getConnections() :
            print(node.getID(), " --> ",
            self.allNodes[con].getID())

# getter
def getNode(self, idx) :
    if idx in self.allNodes :
        return self.allNodes[idx]
    return None

def getAllNodesIds(self) :
    return self.allNodes.keys()
```

```
# methods
def DFS(self, start) :
    # STACK
    visited = [False]*Graph.totalV

    if start in self.allNodes.keys() :
        self.__DFSUtility(node_id = start, visited=visited)
    else :
        print("Start Node not found")

def __DFSUtility(self, node_id, visited) :
    visited = self.__setVisitedTrue(visited=visited, node_id=node_id)
    #print
    print(self.allNodes[node_id].getID(), end = " ")

    #Recursive Stack
    for i in self.allNodes[node_id].getConnections() :
        if visited[self.allNodes[i].getID()] == False :
            self.__DFSUtility(node_id = self.allNodes[i].getID(),
            visited=visited)

def BFS(self, start) :
    #Queue
    visited = [False]*Graph.totalV

    if start in self.allNodes.keys() :
        self.__BFSUtility(node_id = start, visited=visited)
    else :
        print("Start Node not found")

def __BFSUtility(self, node_id, visited) :
    queue = []
    visited = self.__setVisitedTrue(visited=visited, node_id=node_id)

    queue.append(node_id)

    while queue != [] :
        x = queue.pop(0)
        #print
        print(self.allNodes[x].getID(), end = " ")

        for i in self.allNodes[x].getConnections() :
            idx = self.allNodes[i].getID()
            if visited[idx]  == False :
```

```
            queue.append(idx)
            visited = self.__setVisitedTrue(visited=visited,
             node_id=idx)



    def __setVisitedTrue(self, visited, node_id) :
        visited[node_id] = True
        return visited
```

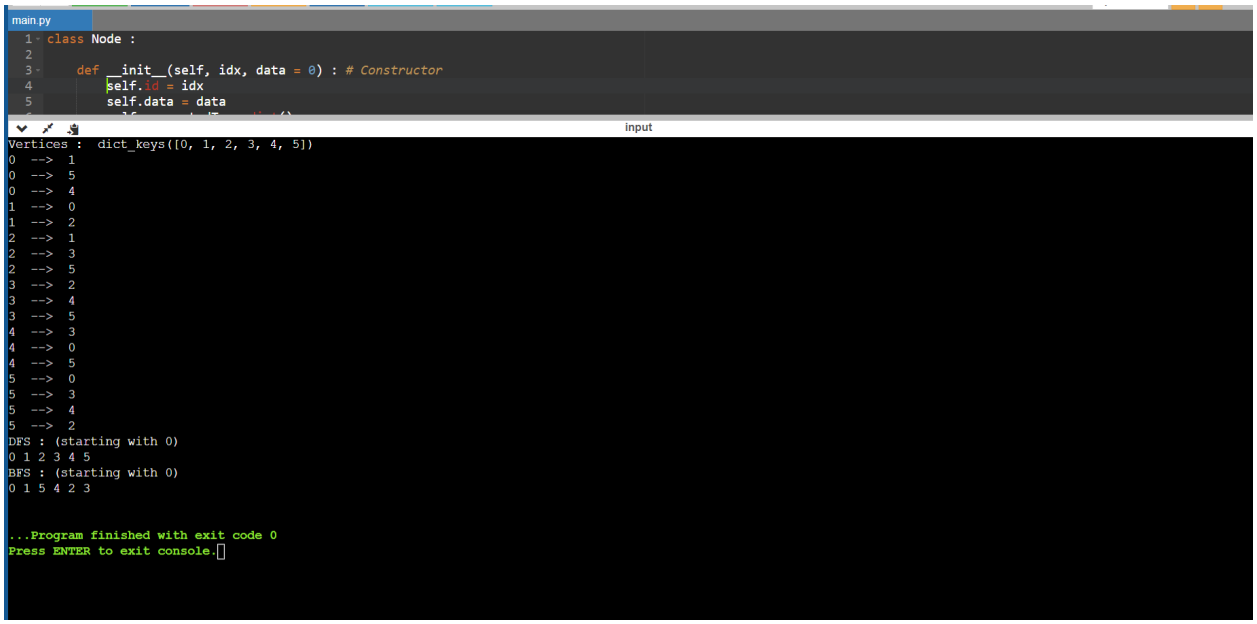
There are some additional functions in the code which are made to check whether graph is created correctly or not.Hence,functions like BFS,DFS and printing is not necessary in the code but added for testing.The segments as number of vertices can be given as global input in the graph.py itself but it is avoided for inclusion of all inputs and connections of grid in connections.py..

This code is been tested with some input with code:

```
def test() :
    g = Graph()
    for i in range(6) :
        g.addNode(i)

    print("Vertices : ",g.getAllNodesIds())

    g.addEdge(src = 0, dst = 1, wt = 5)
    g.addEdge(0,5,2)
    g.addEdge(1,2,4)
    g.addEdge(2,3,9)
    g.addEdge(3,4,7)
    g.addEdge(3,5,3)
    g.addEdge(4,0,1)
    g.addEdge(5,4,8)
    g.addEdge(5,2,1)

    g.printEdges()

    print("DFS : (starting with 0)")
    g.DFS(0)
    print()

    print("BFS : (starting with 0)")
    g.BFS(0)
    print()
```

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

Output:



Hence the graph part of the code is working correctly..

The next part of the code is **sudoku_connections**

```
from graph import Graph

class SudokuConnections :
    def __init__(self) :  # constructor
        self.graph = Graph() # Graph Object
        self.rows = 9
        self.cols = 9
        self.total_blocks = self.rows*self.cols #81
        self.__generateGraph() # Generates all the nodes
        self.connectEdges() # connects all the nodes acc to sudoku constraints
        self.allIds = self.graph.getAllNodesIds() # storing all the ids in a list
    def __generateGraph(self) :
        for idx in range(1, self.total_blocks+1) :
            _ = self.graph.addNode(idx)

    def connectEdges(self) :
        matrix = self.__getGridMatrix()

        head_connections = dict() # head : connections
```

```
    for row in range(9) :
        for col in range(9) :
            head = matrix[row][col] #id of the node
            connections = self.__whatToConnect(matrix, row, col)
            head_connections[head] = connections
    # connect all the edges

    self.__connectThose(head_connections=head_connections)

def __connectThose(self, head_connections) :
    for head in head_connections.keys() : #head is the start idx
        connections = head_connections[head]
        for key in connections :  #get list of all the connections
            for v in connections[key] :
                self.graph.addEdge(src=head, dst=v)


def __whatToConnect(self, matrix, rows, cols) :
    connections = dict()

    row = []
    col = []
    block = []

    # ROWS
    for c in range(cols+1, 9) :
        row.append(matrix[rows][c])

    connections["rows"] = row

    # COLS
    for r in range(rows+1, 9):
        col.append(matrix[r][cols])

    connections["cols"] = col

    # BLOCKS

    if rows%3 == 0 :

        if cols%3 == 0 :

            block.append(matrix[rows+1][cols+1])
```

```
            block.append(matrix[rows+1][cols+2])
            block.append(matrix[rows+2][cols+1])
            block.append(matrix[rows+2][cols+2])

        elif cols%3 == 1 :

            block.append(matrix[rows+1][cols-1])
            block.append(matrix[rows+1][cols+1])
            block.append(matrix[rows+2][cols-1])
            block.append(matrix[rows+2][cols+1])

        elif cols%3 == 2 :

            block.append(matrix[rows+1][cols-2])
            block.append(matrix[rows+1][cols-1])
            block.append(matrix[rows+2][cols-2])
            block.append(matrix[rows+2][cols-1])

    elif rows%3 == 1 :

        if cols%3 == 0 :

            block.append(matrix[rows-1][cols+1])
            block.append(matrix[rows-1][cols+2])
            block.append(matrix[rows+1][cols+1])
            block.append(matrix[rows+1][cols+2])

        elif cols%3 == 1 :

            block.append(matrix[rows-1][cols-1])
            block.append(matrix[rows-1][cols+1])
            block.append(matrix[rows+1][cols-1])
            block.append(matrix[rows+1][cols+1])

        elif cols%3 == 2 :

            block.append(matrix[rows-1][cols-2])
            block.append(matrix[rows-1][cols-1])
            block.append(matrix[rows+1][cols-2])
            block.append(matrix[rows+1][cols-1])

    elif rows%3 == 2 :

        if cols%3 == 0 :
```

```
                block.append(matrix[rows-2][cols+1])
                block.append(matrix[rows-2][cols+2])
                block.append(matrix[rows-1][cols+1])
                block.append(matrix[rows-1][cols+2])

            elif cols%3 == 1 :

                block.append(matrix[rows-2][cols-1])
                block.append(matrix[rows-2][cols+1])
                block.append(matrix[rows-1][cols-1])
                block.append(matrix[rows-1][cols+1])

            elif cols%3 == 2 :

                block.append(matrix[rows-2][cols-2])
                block.append(matrix[rows-2][cols-1])
                block.append(matrix[rows-1][cols-2])
                block.append(matrix[rows-1][cols-1])

        connections["blocks"] = block
        return connections

    def __getGridMatrix(self) :
        matrix = [[0 for cols in range(self.cols)]
        for rows in range(self.rows)]

        count = 1
        for rows in range(9) :
            for cols in range(9):
                matrix[rows][cols] = count
                count+=1
        return matrix
```

In the part of the code,for avoiding the common cases which are included in row and column constraints are been avoided using if loop But using a for loop would have reduced the length of code but it will increase time complexity of calculating all cases hence I avoided that approach

I have tested this part of the code whether it is giving correct output or not using test code:

```
 def test_connections() :
    sudoku = SudokuConnections()
    sudoku.connectEdges()
    print("All node Ids : ")
    print(sudoku.graph.getAllNodesIds())
```

```
    print()
    for idx in sudoku.graph.getAllNodesIds() :
        print(idx, "Connected to->", sudoku.graph.allNodes[idx].getConnections())

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

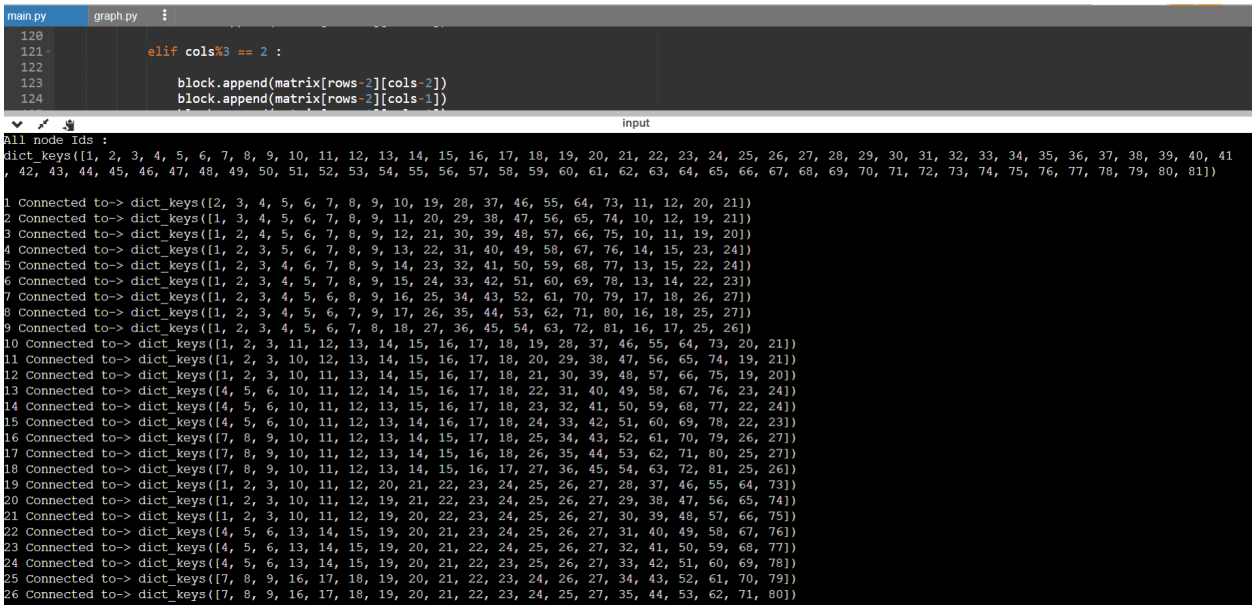
Output:

It is providing correct output,

All node Ids :

dict_keys([1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81])

1 Connected to-> dict_keys([2, 3, 4, 5, 6, 7, 8, 9, 10, 19, 28, 37, 46, 55, 64, 73, 11, 12, 20, 21])
2 Connected to-> dict_keys([1, 3, 4, 5, 6, 7, 8, 9, 11, 20, 29, 38, 47, 56, 65, 74, 10, 12, 19, 21])
3 Connected to-> dict_keys([1, 2, 4, 5, 6, 7, 8, 9, 12, 21, 30, 39, 48, 57, 66, 75, 10, 11, 19, 20])
……..,



Finally all these parts of code are merged under main function

```
from sudoku_connections import SudokuConnections


class SudokuBoard :
    def __init__(self) :
```

```
    self.board = self.getBoard()

    self.sudokuGraph = SudokuConnections()
    self.mappedGrid = self.__getMappedMatrix() # Maps all the ids to the position in the matrix

def __getMappedMatrix(self) :
    matrix = [[0 for cols in range(9)]
    for rows in range(9)]

    count = 1
    for rows in range(9) :
        for cols in range(9):
            matrix[rows][cols] = count
            count+=1
    return matrix

def getBoard(self) :
            return board

def printBoard(self) :

    print("    1 2 3     4 5 6     7 8 9")
    for i in range(len(self.board)) :
        if i%3 == 0  :#and i != 0:
            print("  - - - - - - - - - - - - - ")

        for j in range(len(self.board[i])) :
            if j %3 == 0 :#and j != 0 :
                print(" |  ", end = "")
            if j == 8 :
                print(self.board[i][j]," | ", i+1)
            else :
                print(f"{ self.board[i][j] } ", end="")
    print("  - - - - - - - - - - - - - ")

def is_Blank(self) :

    for row in range(len(self.board)) :
        for col in range(len(self.board[row])) :
            if self.board[row][col] == 0 :
                return (row, col)
    return None
```

```
def graphColoringInitializeColor(self):
    """
    fill the already given colors
    """
    color = [0] * (self.sudokuGraph.graph.totalV+1)
    given = [] # list of all the ids whos value is already given. Thus cannot be changed
    for row in range(len(self.board)) :
        for col in range(len(self.board[row])) :
            if self.board[row][col] != 0 :
                #first get the idx of the position
                idx = self.mappedGrid[row][col]
                #update the color
                color[idx] = self.board[row][col] # this is the main imp part
                given.append(idx)
    return color, given

def solveGraphColoring(self, m =9) :

    color, given = self.graphColoringInitializeColor()
    if self.__graphColorUtility(m =m, color=color, v =1, given=given) is None :
        print(":(")
        return False
    count = 1
    for row in range(9) :
        for col in range(9) :
            self.board[row][col] = color[count]
            count += 1
    return color

def __graphColorUtility(self, m, color, v, given) :

    if v == self.sudokuGraph.graph.totalV+1  :
        return True
    for c in range(1, m+1) :
        if self.__isSafe2Color(v, color, c, given) == True :
            color[v] = c
            if self.__graphColorUtility(m, color, v+1, given) :
                return True
        if v not in given :
            color[v] = 0

def __isSafe2Color(self, v, color, c, given) :

    if v in given and color[v] == c:
```

```
            return True
        elif v in given :
            return False

        for i in range(1, self.sudokuGraph.graph.totalV+1) :
            if color[i] == c and self.sudokuGraph.graph.isNeighbour(v, i) :
                return False
        return True
```

I have given input of the code as:

```
 board = [
            [0,0,0,4,0,0,0,0,0],
            [4,0,9,0,0,6,8,7,0],
            [0,0,0,9,0,0,1,0,0],
            [5,0,4,0,2,0,0,0,9],
            [0,7,0,8,0,4,0,6,0],
            [6,0,0,0,3,0,5,0,2],
            [0,0,1,0,0,7,0,0,0],
            [0,4,3,2,0,0,6,0,5],
            [0,0,0,0,0,5,0,0,0]
        ]
```

It has provided correct output,I have verified it using:

```
def main() :
    s = SudokuBoard()
    print("BEFORE SOLVING ...")
    print("\n\n")
    s.printBoard()
    print("\nSolving ...")
    print("\n\n\nAFTER SOLVING ...")
    print("\n\n")
    s.solveGraphColoring(m=9)
    s.printBoard()

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

Output:

It provided output as:

```
 1 2 3     4 5 6     7 8 9
 - - - - - - - - - - - - -
| 1 8 5 | 4 7 3 | 9 2 6 | 1
| 4 2 9 | 5 1 6 | 8 7 3 | 2
| 3 6 7 | 9 8 2 | 1 5 4 | 3
 - - - - - - - - - - - - -
```

```
| 5 3 4 | 6 2 1 | 7 8 9 | 4
| 9 7 2 | 8 5 4 | 3 6 1 | 5
| 6 1 8 | 7 3 9 | 5 4 2 | 6
 - - - - - - - - - - - - -
| 2 5 1 | 3 6 7 | 4 9 8 | 7
| 7 4 3 | 2 9 8 | 6 1 5 | 8
| 8 9 6 | 1 4 5 | 2 3 7 | 9
```

This output is correct…,

By this way We have solved the problem of sudoku using graph coloring concept…