In [1]:

```
import time
import itertools
import pandas as pd
import numpy as np
from queue import Queue
from collections import deque
from graphviz import Graph, Digraph
from heapq import heapify, heappush, heappop
from math import radians, sin, cos, acos, atan2
```

Helper functions used in both problems

In [2]:

```
def simple_problem_solving_agent(seq, start_state, final_state, search, algo):
    if not seq:
        goal_test = formulate_goal()
        information = formulate_problem(algo)
        seq = search(start_state, final_state, goal_test, information)
        if seq is None:
            return None
    if isinstance(seq, list):  # for bdfs and Astar
        return seq
    if isinstance(final_state, np.ndarray):
        final_state = convert_to_string(final_state)
    seq = get_path(seq, final_state)
    return seq


def goal_test(current_state, final_state):
    return current_state == final_state


def formulate_goal():
    return goal_test


def formulate_problem(algo):
    if algo == "DFS":
        return [deque, "append", "pop"]
    elif algo == "BFS":
        return [Queue, "put", "get"]
    elif algo == "BiDFS_path" or algo == "AStar_path":
        return []
    elif algo == "AStar_puzzle":
        return ["consider path cost"]
    elif algo == "GBFS_puzzle":
        return ["no path cost"]


def get_path(parent: dict, final_state) -> list:
    path = []
    string = final_state
    if isinstance(parent[string], str):
        while parent[string] != string:
            path.append(string)
            string = parent[string]
        path.append(string)
    else:
        while parent[string][3] != string:
            path.append(string)
            string = parent[string][3]
        path.append(string)
    return path
```

Problem 1 - Path finding

In [3]:

```
# Load dataset
df = pd.read_excel("Indian_capitals.xlsx", header=None)

# Fixing typos in dataset
for i in range(2, 6):
    df.loc[i, 0] = "Amaravati"
for i in range(48, 51):
    df.loc[i, 0] = "Shimla"

print(df)
```

	0	1	2
0	Agartala	Aizawl	342
1	Aizawl	Imphal	400
2	Amaravati	Bangalore	663
3	Amaravati	Chennai	448
4	Amaravati	Bhubaneswar	819
5	Amaravati	Raipur	758
6	Bangalore	Panaji	578
7	Bangalore	Chennai	333
8	Bangalore	Thiruvanathapuram	730
9	Bangalore	Mumbai	980
10	Bhopal	Gandhinagar	599
11	Bhubaneswar	Raipur	544
12	Bhubaneswar	Ranchi	455
13	Bhubaneswar	Kolkata	441
14	Chandigarh	Lucknow	742
15	Chandigarh	Jaipur	528
16	Chennai	Thiruvanathapuram	771
17	Dehradun	Lucknow	552
18	Dispur	Shillong	91
19	Dispur	Imphal	482
20	Dispur	Aizawl	462
21	Dispur	Agartala	536
22	Dispur	Itanagar	323
23	Dispur	Kohima	350
24	Hyderabad	Amaravati	271
25	Hyderabad	Bangalore	569
26	Hyderabad	Raipur	783
27	Hyderabad	Mumbai	719
28	Imphal	Kohima	136
29	Jaipur	Gandhinagar	634
30	Jaipur	Bhopal	598
31	Kohima	Itanagar	323
32	Kolkata	Ranchi	395
33	Kolkata	Patna	583
34	Kolkata	Gangtok	675
35	Kolkata	Dispur	1035
36	Lucknow	Jaipur	574
37	Lucknow	Bhopal	615
38	Lucknow	Ranchi	710
39	Lucknow	Patna	539
40	Mumbai	Panaji	542
41	Mumbai	Gandhinagar	553
42	Mumbai	Bhopal	776
43	Patna	Ranchi	327
44	Raipur	Mumbai	1091
45	Raipur	Bhopal	614
46	Raipur	Lucknow	810
47	Raipur	Ranchi	580
48	Shimla	Chandigarh	113
49	Shimla	Dehradun	227
50	Shimla	Lucknow	841
51	Srinagar	Shimla	620
52	Srinagar	Chandigarh	562

The below straight line distances have been calculated using a script and a certain timeout to deal with LocationIQ timeouts.

In [4]:

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22, "Chennai": 0}, "Amaravati": {"Hyderabad": 237.57, "Itanagar": 1791.93, "Disp
ur": 1584.47, "Patna": 1118.76, "Raipur": 538.32, "Panaji": 722.02, "Gandhinaga
r": 1108.59, "Chandigarh": 1624.1, "Shimla": 1656.71, "Srinagar": 2033.07, "Ranc
hi": 913.56, "Bangalore": 502.55, "Thiruvanathapuram": 965.92, "Bhopal": 816.22,
"Mumbai": 855.2, "Imphal": 1672.4, "Shillong": 1550.87, "Aizawl": 1506.46, "Kohi
ma": 1748.03, "Bhubaneswar": 701.11, "Jaipur": 1252.96, "Gangtok": 1463.69, "Che
nnai": 382.86, "Agartala": 1387.47, "Dehradun": 1555.63, "Lucknow": 1148.54, "Ko
lkata": 1062.03, "Amaravati": 0}, "Agartala": {"Hyderabad": 1513.36, "Itanagar":
432.63, "Dispur": 263.07, "Patna": 652.65, "Raipur": 1031.78, "Panaji": 2046.34,
"Gandhinagar": 1899.52, "Chandigarh": 1624.36, "Shimla": 1607.95, "Srinagar": 19
61.01, "Ranchi": 609.14, "Bangalore": 1879.74, "Thiruvanathapuram": 2282.09, "Bh
opal": 1416.44, "Mumbai": 1984.08, "Imphal": 289.78, "Shillong": 203.26, "Aizaw
l": 146.71, "Kohima": 360.94, "Bhubaneswar": 686.38, "Jaipur": 1589.71, "Gangto
k": 472.18, "Chennai": 1664.1, "Amaravati": 1387.47, "Dehradun": 1494.85, "Luckn
ow": 1091.95, "Kolkata": 331.21, "Agartala": 0}, "Dehradun": {"Hyderabad": 1439.
13, "Itanagar": 1559.8, "Dispur": 1423.46, "Patna": 870.53, "Raipur": 1072.31,

"Panaji": 1703.77, "Gandhinagar": 953.83, "Chandigarh": 130.1, "Shimla": 120.23, "Srinagar": 515.46, "Ranchi": 1057.7, "Bangalore": 1929.4, "Thiruvanathapuram": 2424.86, "Bhopal": 789.04, "Mumbai": 1370.68, "Imphal": 1680.79, "Shillong": 1456.95, "Aizawl": 1625.66, "Kohima": 1660.32, "Bhubaneswar": 1364.95, "Jaipur": 436.79, "Gangtok": 1081.58, "Chennai": 1931.36, "Amaravati": 1555.63, "Agartala": 1494.85, "Lucknow": 479.6, "Kolkata": 1339.07, "Dehradun": 0}, "Lucknow": {"Hyderabad": 1081.07, "Itanagar": 1257.34, "Dispur": 1082.99, "Patna": 439.59, "Raipur": 626.74, "Panaji": 1459.48, "Gandhinagar": 926.17, "Chandigarh": 592.7, "Shimla": 599.12, "Srinagar": 994.96, "Ranchi": 586.54, "Bangalore": 1579.93, "Thiruvanathapuram": 2076.91, "Bhopal": 534.69, "Mumbai": 1207.5, "Imphal": 1320.4, "Shillong": 1100.83, "Aizawl": 1233.39, "Kohima": 1324.03, "Bhubaneswar": 885.35, "Jaipur": 507.29, "Gangtok": 761.94, "Chennai": 1531.32, "Amaravati": 1148.54, "Agartala": 1091.95, "Dehradun": 479.6, "Kolkata": 886.4, "Lucknow": 0}, "Kolkata": {"Hyderabad": 1182.27, "Itanagar": 732.78, "Dispur": 529.66, "Patna": 470.59, "Raipur": 708.2, "Panaji": 1715.17, "Gandhinagar": 1608.93, "Chandigarh": 1463.57, "Shimla": 1458.05, "Srinagar": 1837.81, "Ranchi": 322.04, "Bangalore": 1558.75, "Thiruvanathapuram": 1976.96, "Bhopal": 1123.99, "Mumbai": 1661.7, "Imphal": 620.88, "Shillong": 490.55, "Aizawl": 465.75, "Kohima": 688.16, "Bhubaneswar": 364.19, "Jaipur": 1353.47, "Gangtok": 530.1, "Chennai": 1356.22, "Amaravati": 1062.03, "Agartala": 331.21, "Dehradun": 1339.07, "Lucknow": 886.4, "Kolkata": 0}}

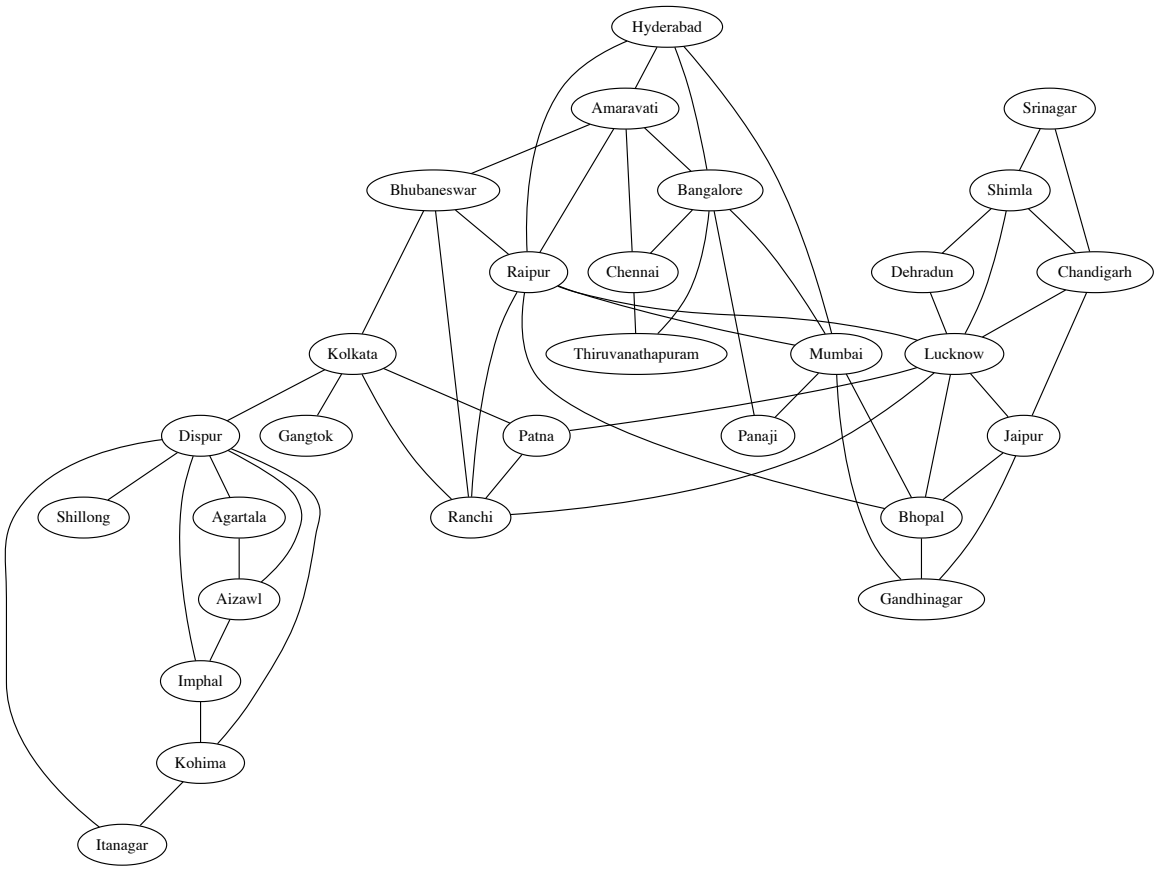
In [5]:

```
# Constructing Graph

rows = df.shape[0]
graph = dict()

dot = Graph(strict=True)
for _, edge in df.iterrows():
    if edge[0] not in graph:
        graph[edge[0]] = dict()
    if edge[1] not in graph:
        graph[edge[1]] = dict()
    graph[edge[0]][edge[1]] = edge[2]
    graph[edge[1]][edge[0]] = edge[2]
    dot.edge(edge[0], edge[1])
dot
```

Out[5]:



In [6]:

```
# Take input

start_state = input("Enter source city: ")
final_state = input("Enter dest city: ")
if start_state not in graph or final_state not in graph:
    raise ValueError("Cities do not exist. Re enter correct input")
```

```
Enter source city: Itanagar
Enter dest city: Srinagar
```

In [7]:

```
# Helper functions
goal_test_ = lambda current_state, dest: current_state == dest
explore = lambda current_state: graph[current_state]


def print_path(path: list, algo: str, src: str, dest: str, dot):
    print(f"Total number of steps taken by {algo}: {len(path)}")
    print(f"Printing the transition cities from {src} to {dest} ------------>")

    trace = dot.copy()
    for i in range(len(path)-1):
        trace.node(path[i], _attributes={"color": "lightblue", "style": "filled"
})
        trace.edge(path[i], path[i+1], _attributes={"color": "red"})

    trace.node(path[-1], _attributes={"color": "lightblue", "style": "filled"})
    return trace
```

In [8]:

```
def DFS_or_BFS(start_city: str, final_city: str, goal_test, information):
    data_structure, add, delete = information
    data_structure = data_structure()
    add = getattr(data_structure, add)
    delete = getattr(data_structure, delete)
    parent = dict()
    parent[start_city] = start_city

    add(start_city)

    while data_structure:
        current_city = delete()

        if goal_test(current_city, final_city):
            return parent

        neighbours = explore(current_city)
        for neighbour, _ in neighbours.items():
            if neighbour not in parent:
                add(neighbour)
                parent[neighbour] = current_city
```

In [9]:

```
def BiDirectional_Search(start_city: str, final_city: str, goal_test, informatio
n):
    src_queue = Queue()
    src_queue.put(start_city)
    src_parent = dict()
    src_parent[start_city] = start_city

    dest_queue = Queue()
    dest_queue.put(final_city)
    dest_parent = dict()
    dest_parent[final_city] = final_city

    if start_city in dest_parent:
         return [start_city]

    while src_queue or dest_queue:
        current_head = src_queue.get()
        current_bottom = dest_queue.get()

        # Explore from top
        neighbours = explore(current_head)
        for neighbour, _ in neighbours.items():
            if neighbour not in src_parent:
                src_queue.put(neighbour)
                src_parent[neighbour] = current_head
                if neighbour in dest_parent:
                    return [neighbour, src_parent, dest_parent]

        # Explore from bottom
        neighbours = explore(current_bottom)
        for neighbour, _ in neighbours.items():
            if neighbour not in dest_parent:
                dest_queue.put(neighbour)
                dest_parent[neighbour] = current_bottom
                if neighbour in src_parent:
                    return [neighbour, src_parent, dest_parent]
```

In [10]:

```
def AStar(start_city: str, final_city: str, goal_test, information):
    start_entry = [straight_distance[start_city][final_city], 0, start_city, sta
rt_city]
    parent = dict()
    parent[start_city] = start_entry

    frontier = list()
    heappush(frontier, start_entry.copy())

    while frontier:
        current_state = heappop(frontier)
        g_n = current_state[1]
        current_city = current_state[2]

        if goal_test(current_city, final_city):
            print(f"Path cost from {start_city} to {final_city}: {parent[final_c
ity][0]} kms.")
            return parent

        neighbours = []
        unchecked_neighbours = explore(current_city)
        for neighbour, distance in unchecked_neighbours.items():
            try:
                dist = straight_distance[neighbour][final_city]
            except:
                pass
            else:
                dist = 0
            neighbours.append([dist+g_n+distance, g_n+distance,
                               neighbour, current_city])

        for neighbour in neighbours:
            if neighbour[2] not in parent:
                heappush(frontier, neighbour)
                parent[neighbour[2]] = neighbour
            elif neighbour[0] < parent[neighbour[2]][0] and parent[neighbour[2]]
in frontier:  # Already present in the parent and not fully explored
                index = frontier.index(parent[neighbour[2]])
                frontier[index] = neighbour
                heapify(frontier)
```

DFS

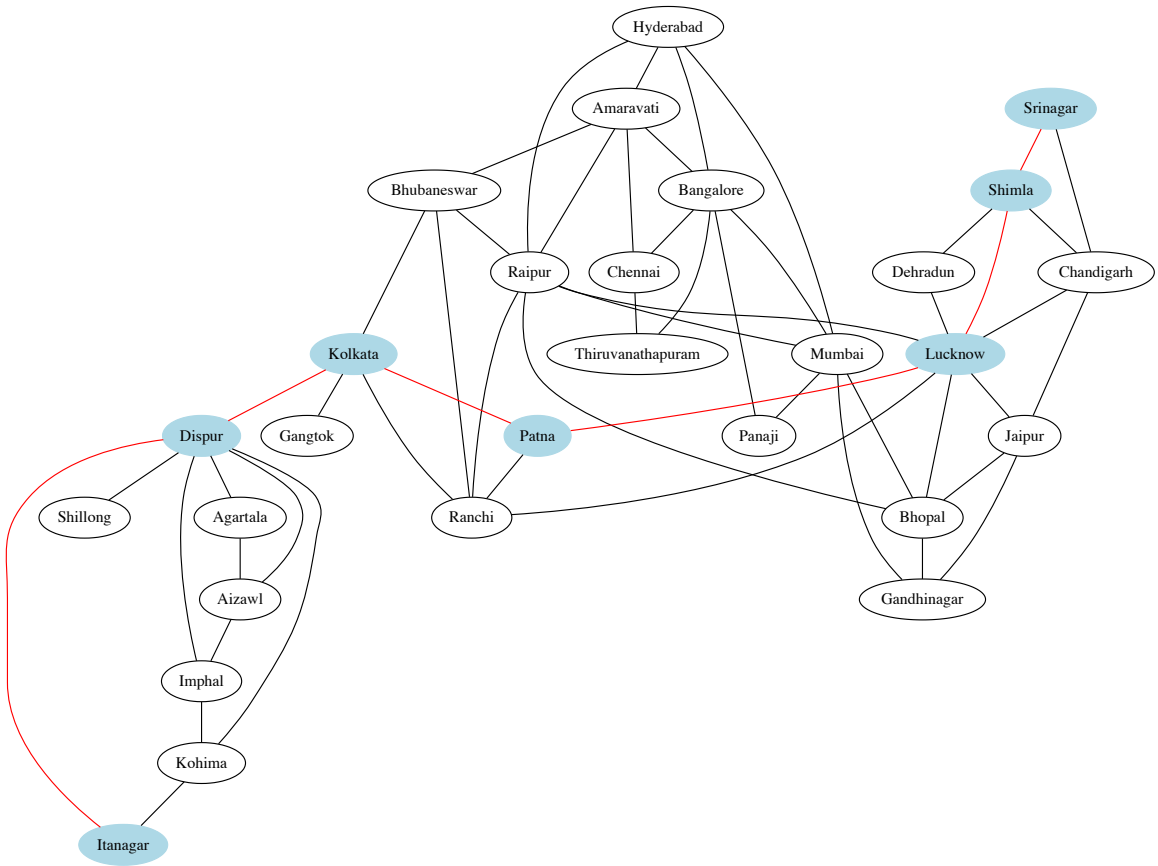
In [11]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, DFS_or_BFS
, "DFS")
t2 = time.perf_counter()
print(f"Total time taken by DFS: {t2-t1} seconds.")

print_path(list(reversed(path)), "DFS", start_state, final_state, dot)
```

```
Total time taken by DFS: 0.00031640499999952 seconds.
Total number of steps taken by DFS: 7
Printing the transition cities from Itanagar to Srinagar -----------
->
```

Out[11]:



BFS

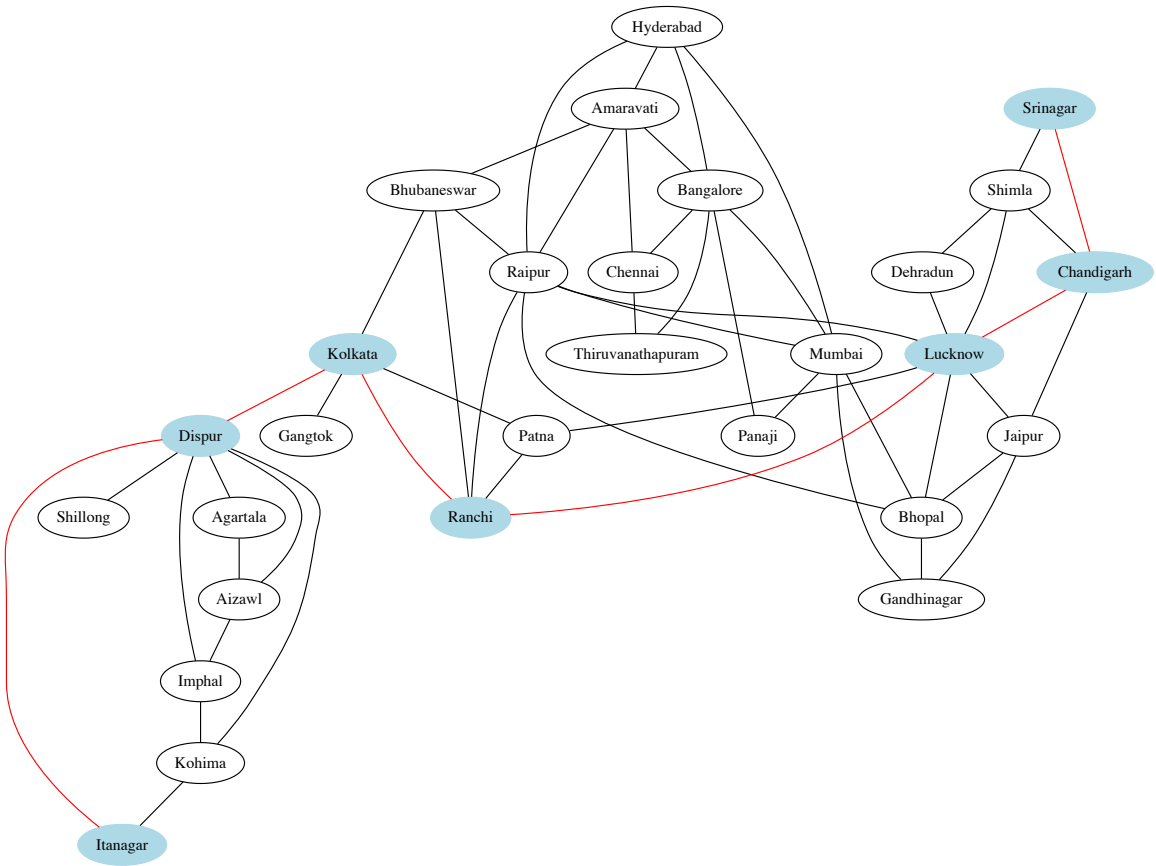
In [12]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, DFS_or_BFS
, "BFS")
t2 = time.perf_counter()
print(f"Total time taken by BFS: {t2-t1} seconds.")

print_path(list(reversed(path)), "BFS", start_state, final_state, dot)
```

```
Total time taken by BFS: 0.0005449820000009709 seconds.
Total number of steps taken by BFS: 7
Printing the transition cities from Itanagar to Srinagar -----------
->
```

Out[12]:



BDFS

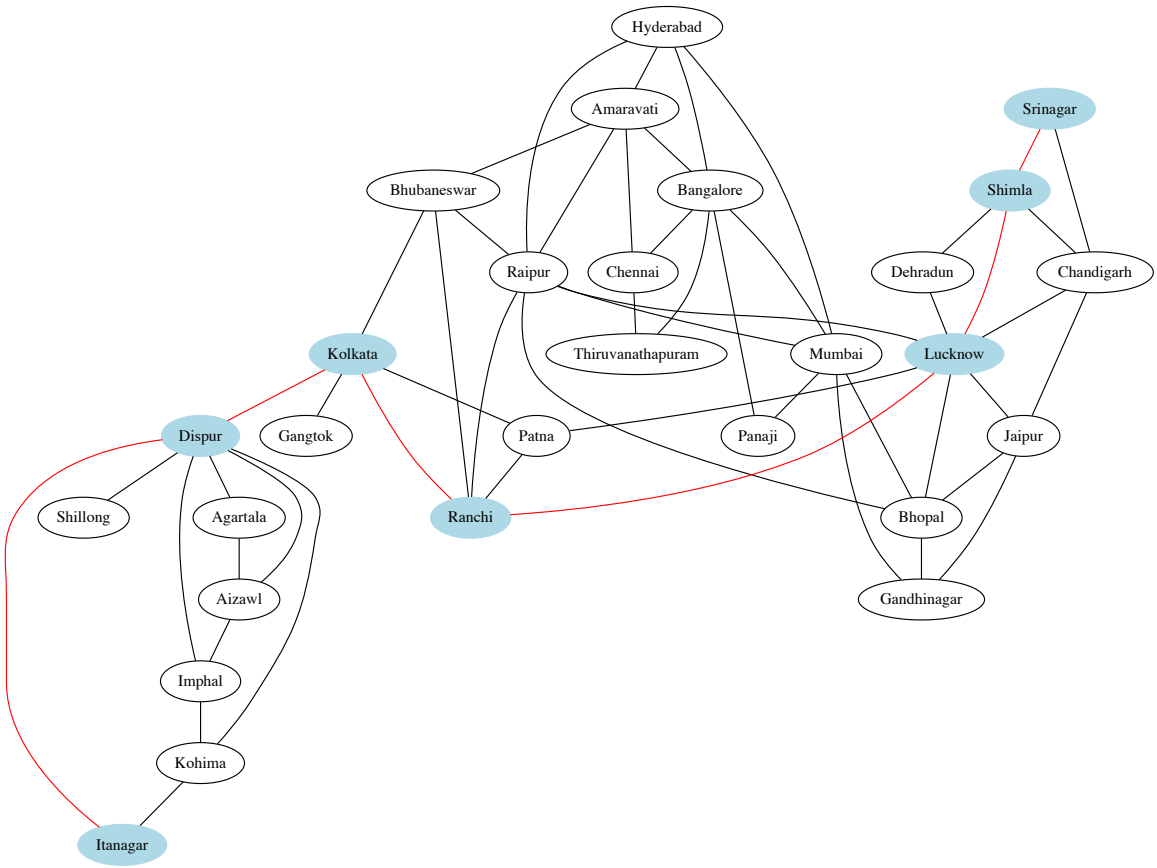
In [13]:

```
t1 = time.perf_counter()
joint, src_parent, dest_parent = simple_problem_solving_agent(list(), start_stat
e, final_state, BiDirectional_Search, "BiDFS_path")
t2 = time.perf_counter()
print(f"Total time taken by BiDirectional_Search: {t2-t1} seconds.")


path = []
path = list(reversed(get_path(src_parent, joint)))
path.extend(get_path(dest_parent, joint)[1:])
print_path(path, "BiDirectional_Search", start_state, final_state, dot)
```

```
Total time taken by BiDirectional_Search: 0.0004527620000018828 seco
nds.
Total number of steps taken by BiDirectional_Search: 7
Printing the transition cities from Itanagar to Srinagar -----------
->
```

Out[13]:



AStar

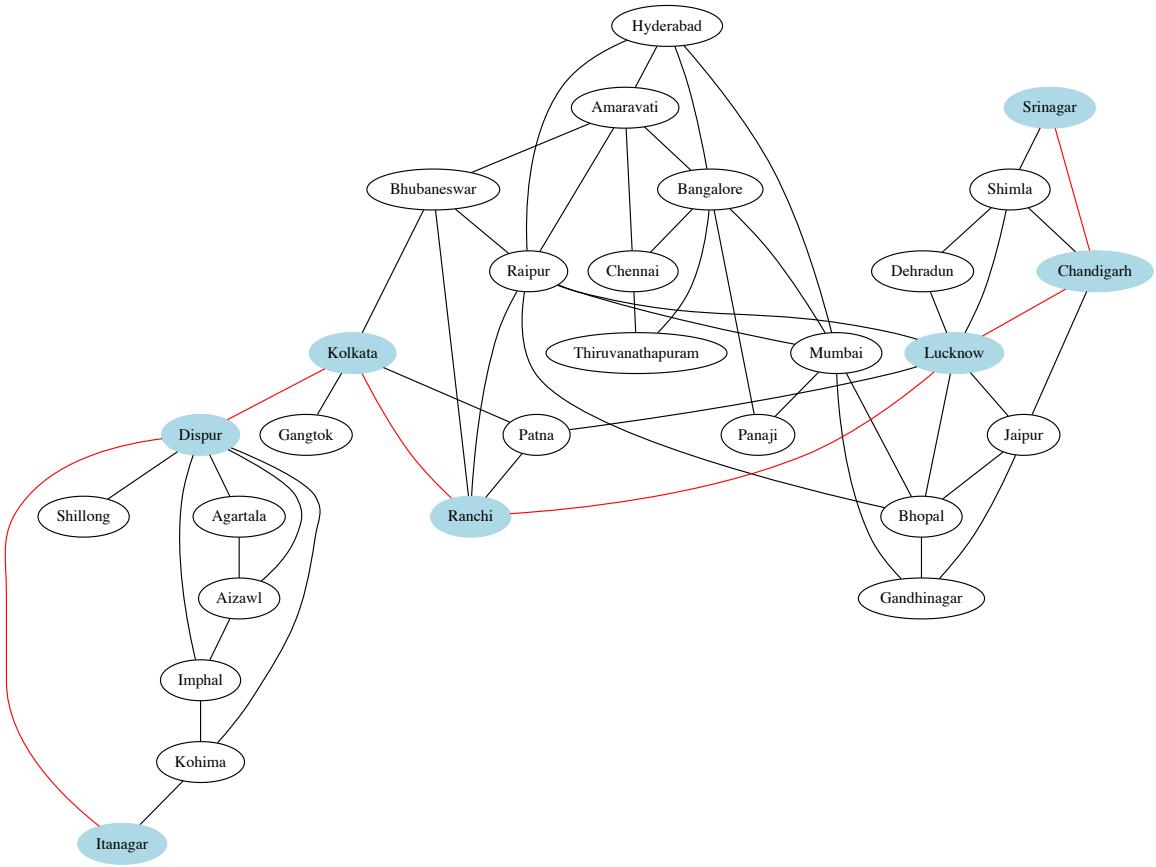
In [14]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, AStar, "AS
tar_path")
t2 = time.perf_counter()
print(f"Total time taken by AStar: {t2-t1} seconds.")

print_path(list(reversed(path)), "AStar", start_state, final_state, dot)
```

```
Path cost from Itanagar to Srinagar: 3767 kms.
Total time taken by AStar: 0.0013542949999987286 seconds.
Total number of steps taken by AStar: 7
Printing the transition cities from Itanagar to Srinagar -----------
->
```

Out[14]:



Problem 2 - 8 Puzzle

In [15]:

```
# Take input

def take_input() -> list:
    err_msg = "Again call take_input function."
    space = list()
    already_present = set()
    for i in range(3):
        row = list(map(int, input(f"Enter {i+1}th row: ").split()))

        if len(row) != 3:
            raise ValueError("Length of row must be three. " + err_msg)

        for num in row:
            if num < 0 or num > 8:
                raise ValueError(f"Invalid number {num}. Enter number between 0
 and 8. " + err_msg)
            if num in already_present: # Constant time lookup in set
                raise ValueError(f"Wrong input format. {num} already present. "
+ err_msg)
            else:
                already_present.add(num)
        space.append(row)

    return space

start_state = take_input()
```

```
Enter 1th row: 7 2 4
Enter 2th row: 5 0 6
Enter 3th row: 8 3 1
```

In [16]:

```
convert_to_string = lambda l: " ".join(map(str, l))
convert_to_np = lambda s: np.array(list(map(int, s.split())))


def explore_puzzle(current_state: np.ndarray) -> list:
    neighbours = []
    current_index = int(np.where(current_state == 0)[0])
    if current_index < 6: # Zero down
        neighbour = current_state.copy()
        neighbour[current_index] = neighbour[current_index+3]
        neighbour[current_index+3] = 0
        neighbours.append(neighbour)

    if current_index > 2: # Zero up
        neighbour = current_state.copy()
        neighbour[current_index] = neighbour[current_index-3]
        neighbour[current_index-3] = 0
        neighbours.append(neighbour)

    if current_index not in [2, 5, 8]: # Zero right
        neighbour = current_state.copy()
        neighbour[current_index] = neighbour[current_index+1]
        neighbour[current_index+1] = 0
        neighbours.append(neighbour)

    if current_index not in [0, 3, 6]: # Zero left
        neighbour = current_state.copy()
        neighbour[current_index] = neighbour[current_index-1]
        neighbour[current_index-1] = 0
        neighbours.append(neighbour)

    return neighbours


def print_path_puzzle(path: list, algo: str):
    print(f"Total number of steps taken by {algo}: {len(path)}")
    print("Printing the transition states from start to final ------------>")
    for string in reversed(path):
        l = convert_to_np(string)
        print(np.array([l[:3], l[3:6], l[6:]]))
        print()


def manhattan_distance(current_state: np.ndarray) -> int:
    h = 0
    for index, value in enumerate(current_state):
        current_x, current_y = index//3, index%3
        actual_x, actual_y = value//3, value%3
        h += (abs(actual_x-current_x) + abs(actual_y-current_y))
    return h


def check_solvability(arr: np.ndarray) -> bool:
    inv_count = 0
    for i in range(len(arr)):
        for j in range(i+1, len(arr)):
            if (arr[j] and arr[i] and arr[i] > arr[j]):
                inv_count += 1
    return inv_count%2 == 0
```

```
start_state = np.array(start_state).flatten()
start_string = convert_to_string(start_state)
final_state = np.array(list(range(9)))
final_string = convert_to_string(final_state)

print("Starting state in np.ndarray: ", start_state)
print("Starting state in string: ", repr(start_string))
print("Final state in np.ndarray: ", final_state)
print("Final state in string: ", repr(final_string))

possible_to_solve = check_solvability(start_state)
if possible_to_solve:
    print("Puzzle is solvable.")
else:
    print("Puzzle is unsolvable. No need to go further. Change the input.")
```

```
Starting state in np.ndarray:  [7 2 4 5 0 6 8 3 1]
Starting state in string:  '7 2 4 5 0 6 8 3 1'
Final state in np.ndarray:  [0 1 2 3 4 5 6 7 8]
Final state in string:  '0 1 2 3 4 5 6 7 8'
Puzzle is solvable.
```

In [17]:

```
def DFS_or_BFS_puzzle(start_state: np.ndarray, final_state: np.ndarray, goal_tes
t, information):
    data_structure, add, delete = information
    data_structure = data_structure()
    add = getattr(data_structure, add)
    delete = getattr(data_structure, delete)
    parent = dict()
    parent[start_string] = start_string

    add(start_state)

    while data_structure:
        current_state = delete()

        if goal_test(convert_to_string(current_state), convert_to_string(final_s
tate)):
            return parent

        neighbours = explore_puzzle(current_state)
        current_string = convert_to_string(current_state)
        for neighbour in neighbours:
            n_string = convert_to_string(neighbour)
            if n_string not in parent:
                add(neighbour)
                parent[n_string] = current_string
```

In [18]:

```
def AStar_or_GreedyBFS_puzzle(start_state: np.ndarray, final_state: np.ndarray,
goal_test, path_cost):
    path_cost = path_cost[0]
    start_entry = [manhattan_distance(start_state), 0, start_string, start_strin
g]
    parent = dict()
    parent[start_string] = start_entry

    frontier = list()
    heappush(frontier, start_entry.copy())

    while frontier:
        current_state = heappop(frontier)
        g_n = current_state[1]
        current_string = current_state[2]
        current_state = convert_to_np(current_state[2])

        if goal_test(convert_to_string(current_state), convert_to_string(final_s
tate)):
            return parent

        neighbours = []
        unchecked_neighbours = explore_puzzle(current_state)
        for neighbour in unchecked_neighbours:
            m_dist = manhattan_distance(neighbour)
            neighbours.append([m_dist+g_n+1 if path_cost=="consider path cost" e
lse m_dist,
                               g_n+1 if path_cost=="consider path cost" else 0,
                               convert_to_string(neighbour), current_string])

        for neighbour in neighbours:
            if neighbour[2] not in parent:
                heappush(frontier, neighbour)
                parent[neighbour[2]] = neighbour
            elif neighbour[0] < parent[neighbour[2]][0] and parent[neighbour[2]]
in frontier:  # Already present in the parent and not fully explored
                index = frontier.index(parent[neighbour[2]])
                frontier[index] = neighbour
                heapify(frontier)
```

DFS

In [19]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, DFS_or_BFS
_puzzle, "DFS")
t2 = time.perf_counter()
print(f"Total time taken by DFS: {t2-t1} seconds.")
print(f"Total number of steps taken by DFS: {len(path)}")
```

```
Total time taken by DFS: 10.485448024999997 seconds.
Total number of steps taken by DFS: 31157
```

BFS

In [20]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, DFS_or_BFS
_puzzle, "BFS")
t2 = time.perf_counter()
print(f"Total time taken by BFS: {t2-t1} seconds.")

print_path_puzzle(path, "BFS")
```

```
Total time taken by BFS: 13.696138321999996 seconds.
Total number of steps taken by BFS: 27
Printing the transition states from start to final ------------>
[[7 2 4]
 [5 0 6]
 [8 3 1]]

[[7 2 4]
 [0 5 6]
 [8 3 1]]

[[0 2 4]
 [7 5 6]
 [8 3 1]]

[[2 0 4]
 [7 5 6]
 [8 3 1]]

[[2 5 4]
 [7 0 6]
 [8 3 1]]

[[2 5 4]
 [7 3 6]
 [8 0 1]]

[[2 5 4]
 [7 3 6]
 [0 8 1]]

[[2 5 4]
 [0 3 6]
 [7 8 1]]

[[2 5 4]
 [3 0 6]
 [7 8 1]]

[[2 5 4]
 [3 6 0]
 [7 8 1]]

[[2 5 0]
 [3 6 4]
 [7 8 1]]

[[2 0 5]
 [3 6 4]
 [7 8 1]]

[[0 2 5]
 [3 6 4]
 [7 8 1]]

[[3 2 5]
 [0 6 4]
 [7 8 1]]

[[3 2 5]
 [6 0 4]
```

```
 [7 8 1]]

[[3 2 5]
 [6 4 0]
 [7 8 1]]

[[3 2 5]
 [6 4 1]
 [7 8 0]]

[[3 2 5]
 [6 4 1]
 [7 0 8]]

[[3 2 5]
 [6 0 1]
 [7 4 8]]

[[3 2 5]
 [6 1 0]
 [7 4 8]]

[[3 2 0]
 [6 1 5]
 [7 4 8]]

[[3 0 2]
 [6 1 5]
 [7 4 8]]

[[3 1 2]
 [6 0 5]
 [7 4 8]]

[[3 1 2]
 [6 4 5]
 [7 0 8]]

[[3 1 2]
 [6 4 5]
 [0 7 8]]

[[3 1 2]
 [0 4 5]
 [6 7 8]]

[[0 1 2]
 [3 4 5]
 [6 7 8]]
```

A*

In [21]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, AStar_or_G
reedyBFS_puzzle, "AStar_puzzle")
t2 = time.perf_counter()
print(f"Total time taken by AStar: {t2-t1} seconds.")

print_path_puzzle(path, "AStar")
```

```
Total time taken by AStar: 0.6696746499999904 seconds.
Total number of steps taken by AStar: 27
Printing the transition states from start to final ------------>
[[7 2 4]
 [5 0 6]
 [8 3 1]]

[[7 2 4]
 [0 5 6]
 [8 3 1]]

[[0 2 4]
 [7 5 6]
 [8 3 1]]

[[2 0 4]
 [7 5 6]
 [8 3 1]]

[[2 5 4]
 [7 0 6]
 [8 3 1]]

[[2 5 4]
 [7 3 6]
 [8 0 1]]

[[2 5 4]
 [7 3 6]
 [0 8 1]]

[[2 5 4]
 [0 3 6]
 [7 8 1]]

[[2 5 4]
 [3 0 6]
 [7 8 1]]

[[2 5 4]
 [3 6 0]
 [7 8 1]]

[[2 5 0]
 [3 6 4]
 [7 8 1]]

[[2 0 5]
 [3 6 4]
 [7 8 1]]

[[0 2 5]
 [3 6 4]
 [7 8 1]]

[[3 2 5]
 [0 6 4]
 [7 8 1]]

[[3 2 5]
 [6 0 4]
```

```
 [7 8 1]]

[[3 2 5]
 [6 4 0]
 [7 8 1]]

[[3 2 5]
 [6 4 1]
 [7 8 0]]

[[3 2 5]
 [6 4 1]
 [7 0 8]]

[[3 2 5]
 [6 4 1]
 [0 7 8]]

[[3 2 5]
 [0 4 1]
 [6 7 8]]

[[3 2 5]
 [4 0 1]
 [6 7 8]]

[[3 2 5]
 [4 1 0]
 [6 7 8]]

[[3 2 0]
 [4 1 5]
 [6 7 8]]

[[3 0 2]
 [4 1 5]
 [6 7 8]]

[[3 1 2]
 [4 0 5]
 [6 7 8]]

[[3 1 2]
 [0 4 5]
 [6 7 8]]

[[0 1 2]
 [3 4 5]
 [6 7 8]]
```

It is clear from the above statistics that A *algorithm takes about 90 percent less time as compared to BFS. The path found from A* and BFS is same.

Greedy Best First Search

In [22]:

```
t1 = time.perf_counter()
path = simple_problem_solving_agent(list(), start_state, final_state, AStar_or_G
reedyBFS_puzzle, "GBFS_puzzle")
t2 = time.perf_counter()
print(f"Total time taken by Greedy Best First Search: {t2-t1} seconds.")

print_path_puzzle(path, "Greedy Best First Search")
```

```
Total time taken by Greedy Best First Search: 0.02401102899997909 se
conds.
Total number of steps taken by Greedy Best First Search: 31
Printing the transition states from start to final ------------>
[[7 2 4]
 [5 0 6]
 [8 3 1]]

[[7 2 4]
 [0 5 6]
 [8 3 1]]

[[0 2 4]
 [7 5 6]
 [8 3 1]]

[[2 0 4]
 [7 5 6]
 [8 3 1]]

[[2 4 0]
 [7 5 6]
 [8 3 1]]

[[2 4 6]
 [7 5 0]
 [8 3 1]]

[[2 4 6]
 [7 0 5]
 [8 3 1]]

[[2 4 6]
 [7 3 5]
 [8 0 1]]

[[2 4 6]
 [7 3 5]
 [0 8 1]]

[[2 4 6]
 [0 3 5]
 [7 8 1]]

[[2 4 6]
 [3 0 5]
 [7 8 1]]

[[2 0 6]
 [3 4 5]
 [7 8 1]]

[[2 6 0]
 [3 4 5]
 [7 8 1]]

[[2 6 5]
 [3 4 0]
 [7 8 1]]

[[2 6 5]
```

```
 [3 0 4]
 [7 8 1]]

[[2 0 5]
 [3 6 4]
 [7 8 1]]

[[0 2 5]
 [3 6 4]
 [7 8 1]]

[[3 2 5]
 [0 6 4]
 [7 8 1]]

[[3 2 5]
 [6 0 4]
 [7 8 1]]

[[3 2 5]
 [6 4 0]
 [7 8 1]]

[[3 2 5]
 [6 4 1]
 [7 8 0]]

[[3 2 5]
 [6 4 1]
 [7 0 8]]

[[3 2 5]
 [6 4 1]
 [0 7 8]]

[[3 2 5]
 [0 4 1]
 [6 7 8]]

[[3 2 5]
 [4 0 1]
 [6 7 8]]

[[3 2 5]
 [4 1 0]
 [6 7 8]]

[[3 2 0]
 [4 1 5]
 [6 7 8]]

[[3 0 2]
 [4 1 5]
 [6 7 8]]

[[3 1 2]
 [4 0 5]
 [6 7 8]]

[[3 1 2]
 [0 4 5]
```

```
 [6 7 8]]

[[0 1 2]
 [3 4 5]
 [6 7 8]]
```

Greedy Best First Search take 99% less time than BFS but it is not a complete algorithm. It can stuck if there is no path found towards the goal state.

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AI Assignment