NUS | Computing
National University of Singapore

IT5001 Software Development Fundamentals

16. Miscellaneous

Agenda

- Decorators for Memoization
- Graph Problems
  - Route Problems
  - Shortest Distance

Decorators

- Decorator is a closure
  - Additionally, outer function accepts a function as input argument

- Modify input function's behaviour with an inner function without explicitly changing input function's code

- Example

```
def deco(func):
    def wrapper():
        #statements
        func()
        pass
    return wrapper

def f():
    pass

f = deco(f)
```

```
def deco(func):
    def wrapper():
        #statements
        func()
        pass
    return wrapper

@deco
def f():
    pass
```

Decorators - Example

```python
def my_decorator(func):
    def wrapper():
        print('Hello')
        func()
        print('Welcome')
    return wrapper

def func():
    print('IT5001')

decorated_func = my_decorator(func)

decorated_func()
```

```python
def my_decorator(func):
    def wrapper():
        print('Hello')
        func()
        print('Welcome')
    return wrapper

@my_decorator
def func():
    print('IT5001')


func()
```

Decorators: Example

- Decorating functions that has arguments

```
def my_decorator(func):
    def wrapper(*args, **kwargs):
        #statements
        func(*args, **kwargs)
    return wrapper

@my_decorator
def f():
    pass
```

Decorators: Example

- Decorating functions that has arguments

```
def my_decorator(func):
    def wrapper(*args, **kwargs):
        print('executing decorated function')
        return func(*args, **kwargs)
    return wrapper
```

```
@my_decorator
def g(x, y = None):
    return x**2+y**2
```

Decorators: Applications

- Profiling
  - For timing functions

- Logging
  - For debugging

- Caching
  - For Memoization

Decorators for Caching

```
def cache(func) :
    memo = {}
    def wrap (*args):
        if args not in memo:
            memo[args] = func(*args)
        return memo[args]
    return wrap
```

Fibonacci using decorators

```
def fibm(n):
    if n in fibans.keys():
        return fibans[n]

    if (n == 0):
        ans = 0
    elif (n == 1):
        ans = 1
    else:
        ans = fibm(n-1)+fibm(n-2)
    return ans
print(fibm(10))
```

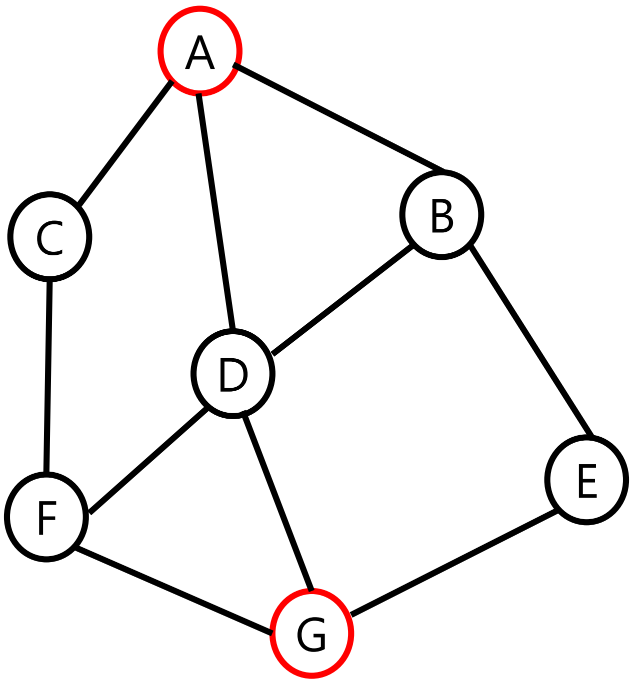
```
@cache
def fib(n):
    if n ==0:
        return 0
    if n <= 2:
        return 1
    return fib(n-1) + fib(n-2)

print(fib(50))
```

Graphs

Path Between Vertices

Breadth-First Search

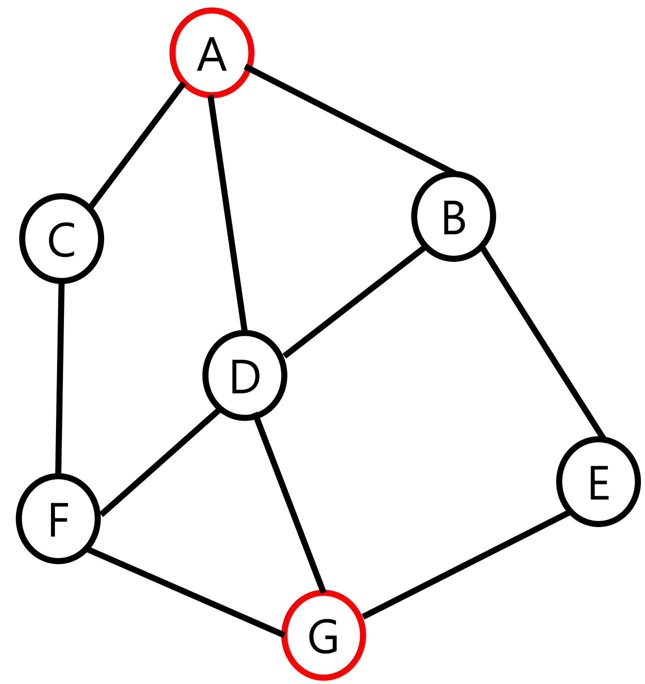


Objective:

Checking if a path exists from vertex A to vertex G

Graph Representation

- Consists of two components
  - ➢ Vertices
    - A,B,C,D, E, ….
  - ➢ Edges
    - (A,B), (A,C), (B,D)….
- How to represent it?
  - ➢ Edge List
    - Contains list of all edges
  - ➢ Adjacency List/Dictionary
    - List of vertices that are adjacent to a given vertex
    - Can use dictionary
      - Provides mapping between each vertex and its neighbors
- Assume we are given list of edges, i.e., edge list



Edge List to Adjacency List

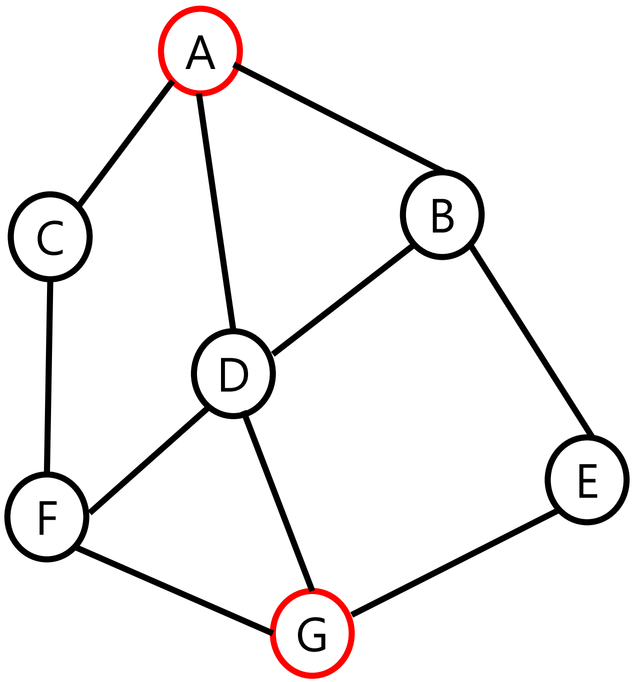
```
def edgeList_to_adjList(edgeList):
    adjacencyList = {}
    for a, b in edgeList:
        if a not in adjacencyList:
            adjacencyList[a] = []
        if b not in adjacencyList:
            adjacencyList[b] = []
        adjacencyList[a].append(b)
        adjacencyList[b].append(a)
    return adjacencyList
```

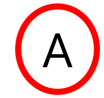
Breadth-First Search

```
def can_travel_bfs(edgeList,source,destination):
    adjacencyList = edgeList_to_adjList(edgeList)
    visited = set()
    frontier = [source]
    while frontier:
        current = frontier.pop(0)
        if current == destination:
            return True
        if current not in adjacencyList or current in visited:
            continue
        visited.add(current)
        frontier.extend(adjacencyList[current])
    return False
```

```
print(can_travel_bfs(edge_list,'A','C'))
```

Breadth-First Search





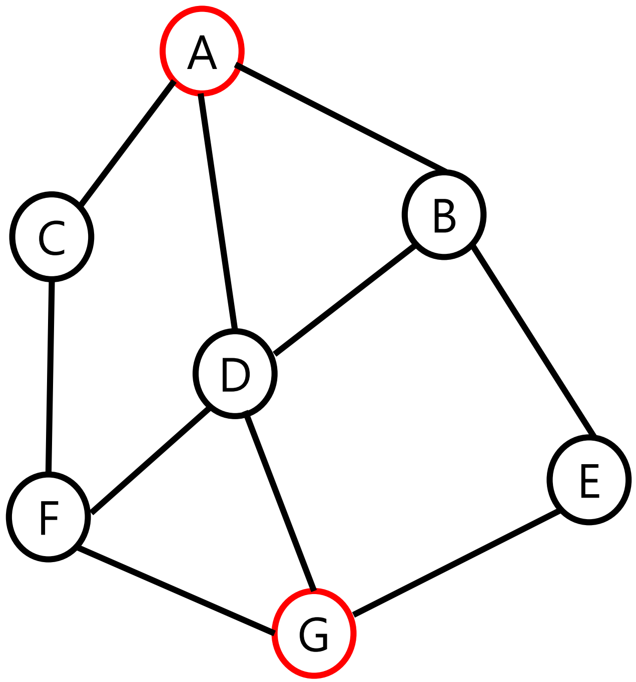
current $\neq$ destination

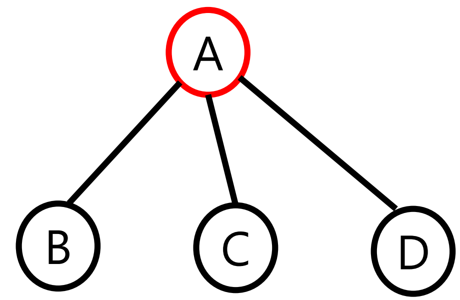
current $not\ in$ visited

visited = {}
frontier = ['A']

```
print(can_travel_bfs(edge_list,'A','C'))
```

Breadth-First Search



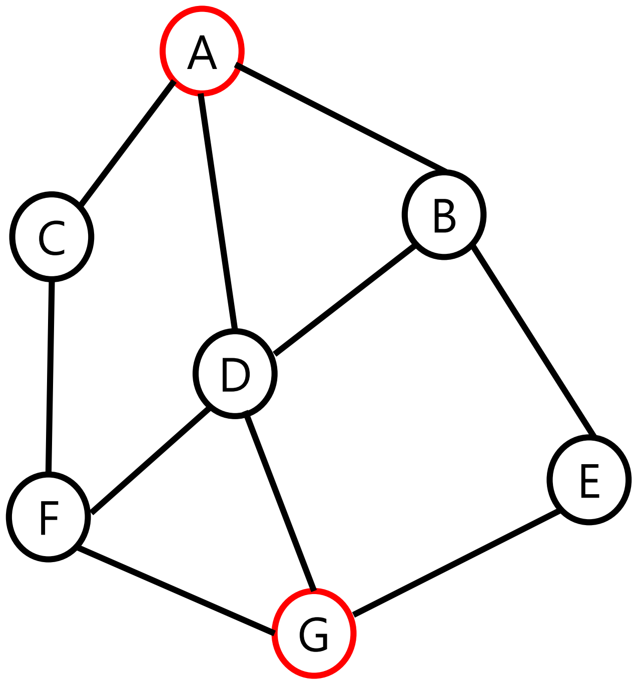


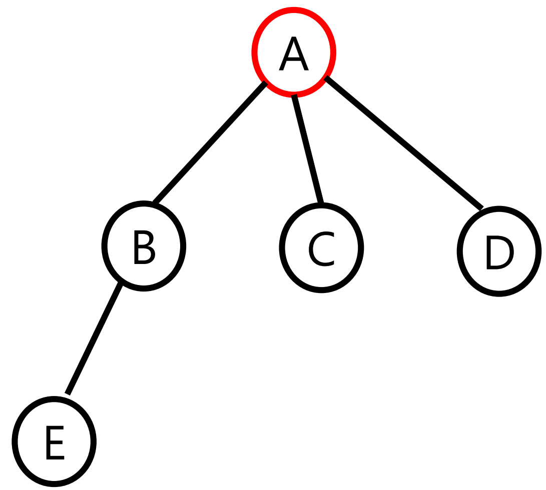
current ≠ destination

current $not\ in$ visited

visited = {'A'}
frontier = ['B', 'C', 'D']

Breadth-First Search



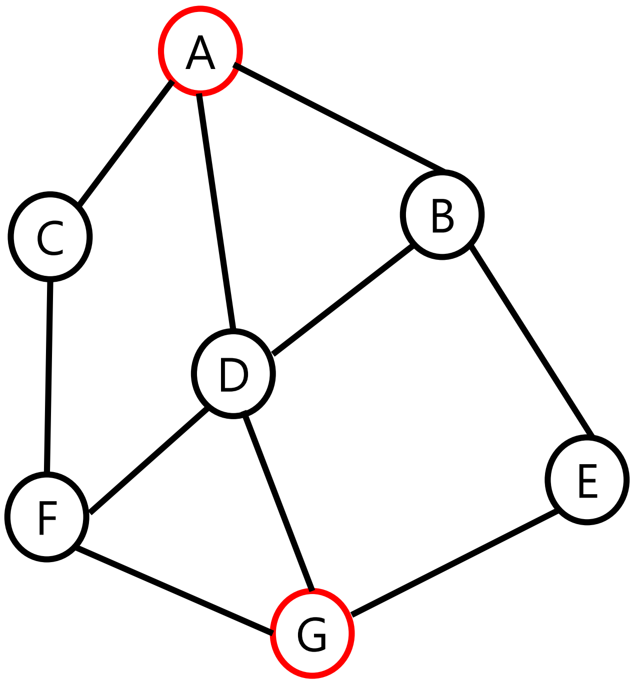


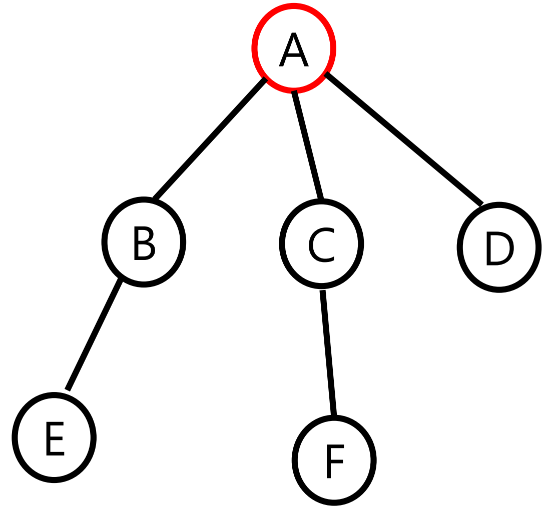
current $\neq$ destination

current $not\ in$ visited

visited = {'A', 'B'}
frontier = ['C', 'D', 'E']

Breadth-First Search



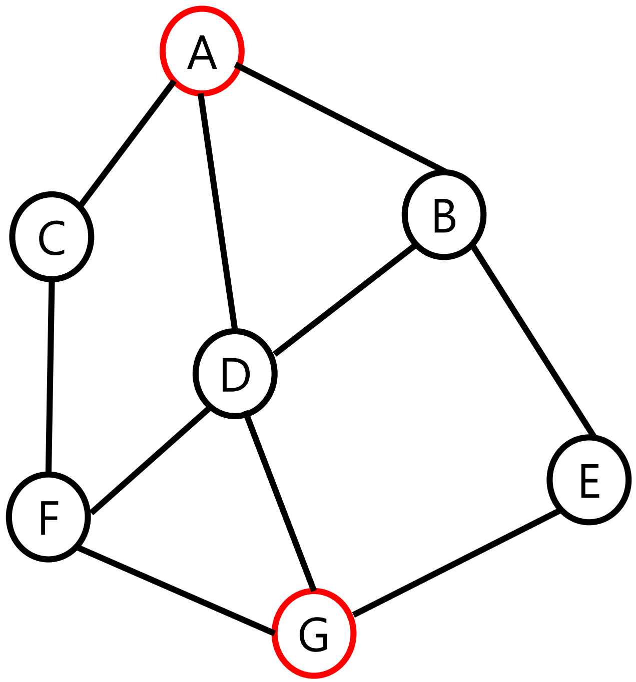


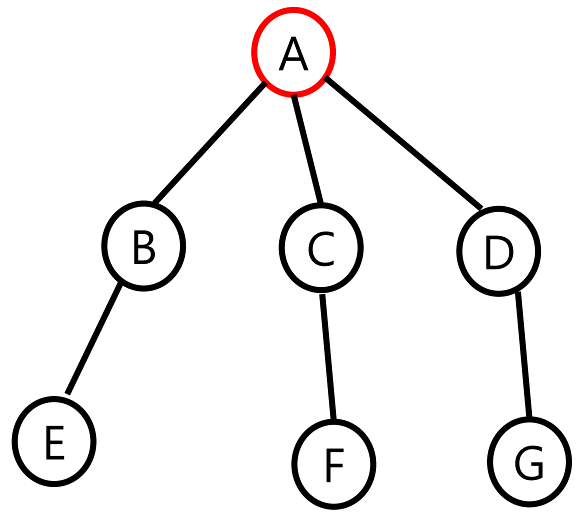
current $\neq$ destination

current $not\ in$ visited

visited = {'A', 'B', 'C'}
frontier = ['D', 'E', 'F']

Breadth-First Search



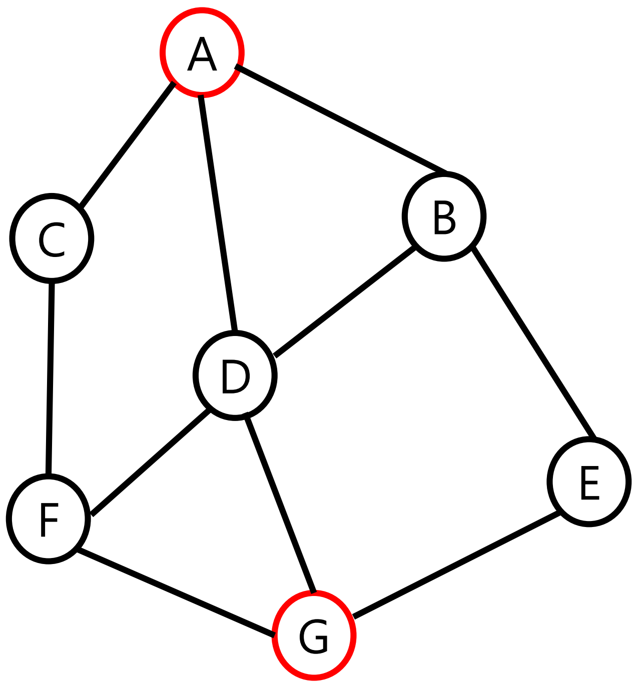


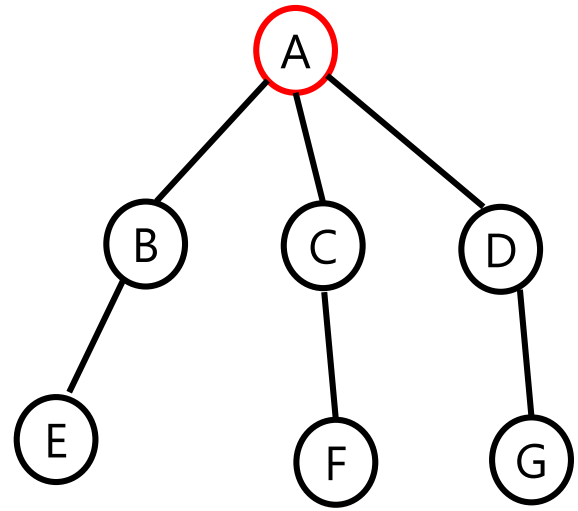
current $not\ in$ visited

current $\neq$ destination

visited = {'A', 'B', 'C', 'D'}
frontier = ['E', 'F', 'G']

Breadth-First Search



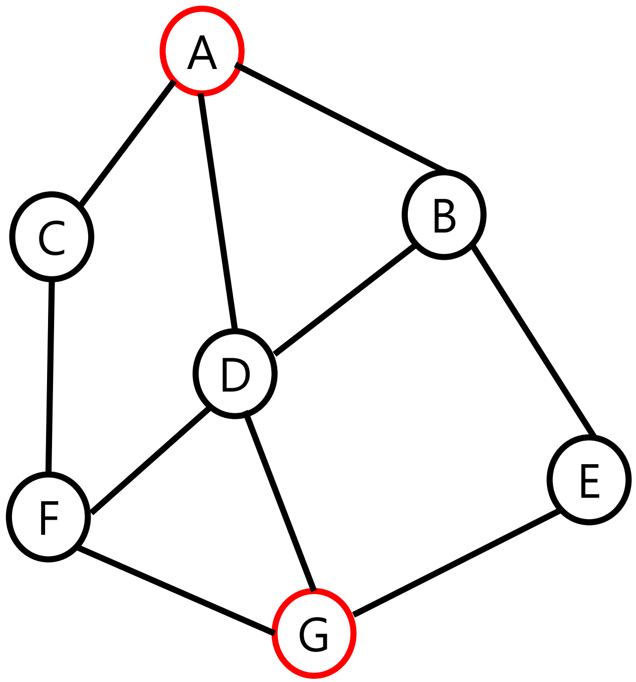


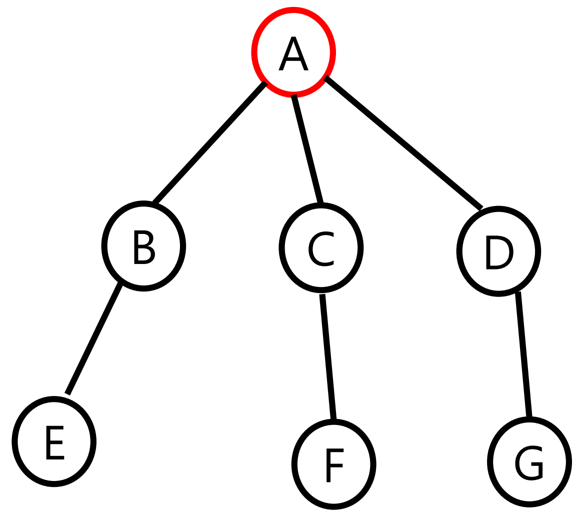
current $\neq$ destination

current $not\ in$ visited

visited = {'A', 'B', 'C', 'D', 'E'}
frontier = ['F', 'G']

Breadth-First Search

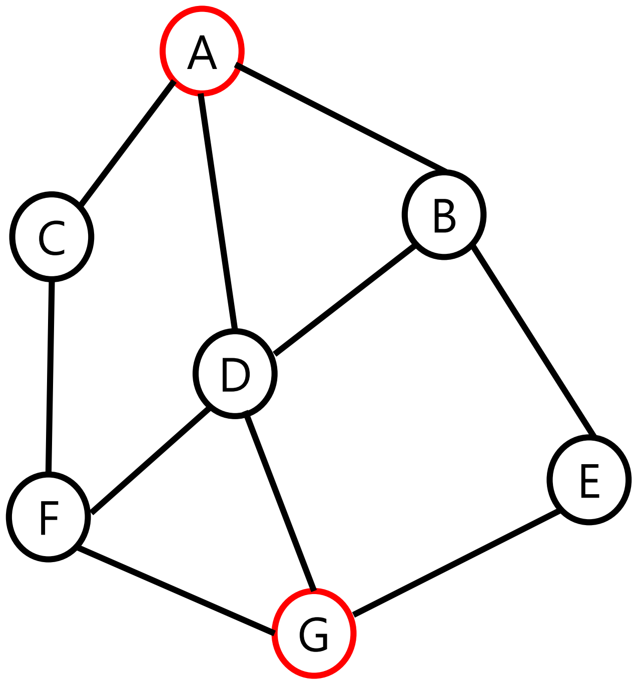


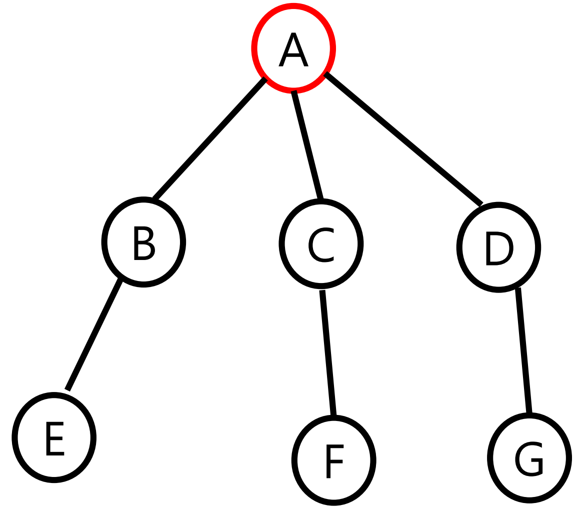


current $\neq$ destination
current $not\ in$ visited

visited = {'A', 'B', 'C', 'D', 'E'}
frontier = ['G']

Breadth-First Search





current == destination

Returns $True$

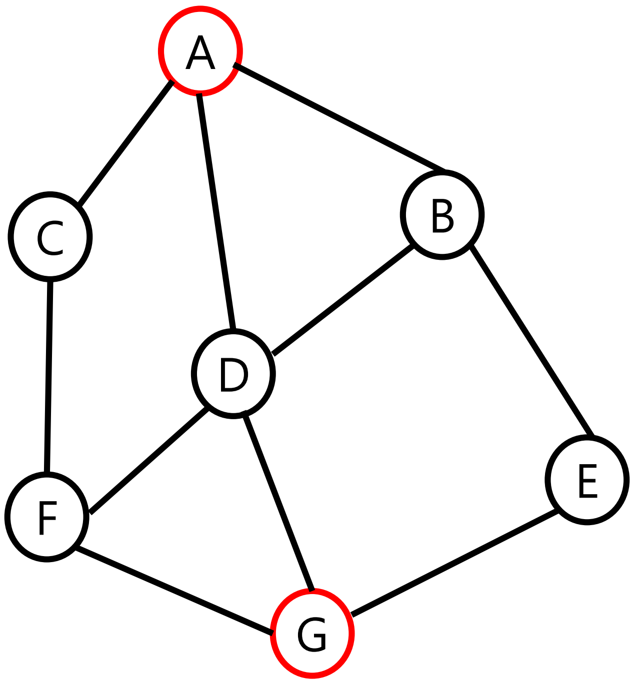
visited = {'A', 'B', 'C', 'D', 'E'}
frontier = [ ]

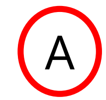
Depth-First Search

```
def can_travel_dfs(edgeList,source,destination):
    adjacencyList = edgeList_to_adjList(edgeList)
    visited = set()
    frontier = [source]
    while frontier:
        current = frontier.pop()
        if current == destination:
            return True
        if current not in adjacencyList or current in visited:
            continue
        visited.add(current)
        frontier.extend(adjacencyList[current])
    return False
```

```
print(can_travel_dfs(edge_list,'A','C'))
```

Depth-First Search

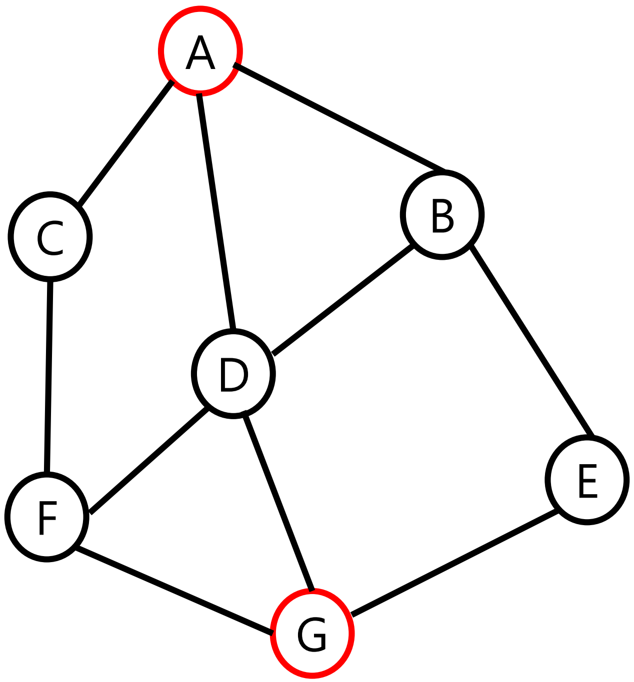


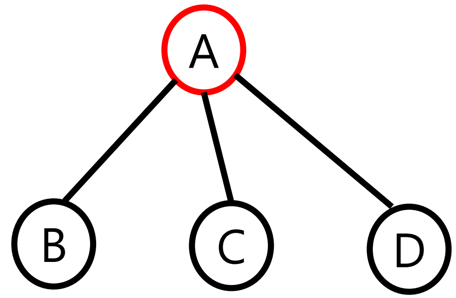


current $\neq$ destination
current $not\ in$ visited

visited = {}
frontier = ['A']

Depth-First Search

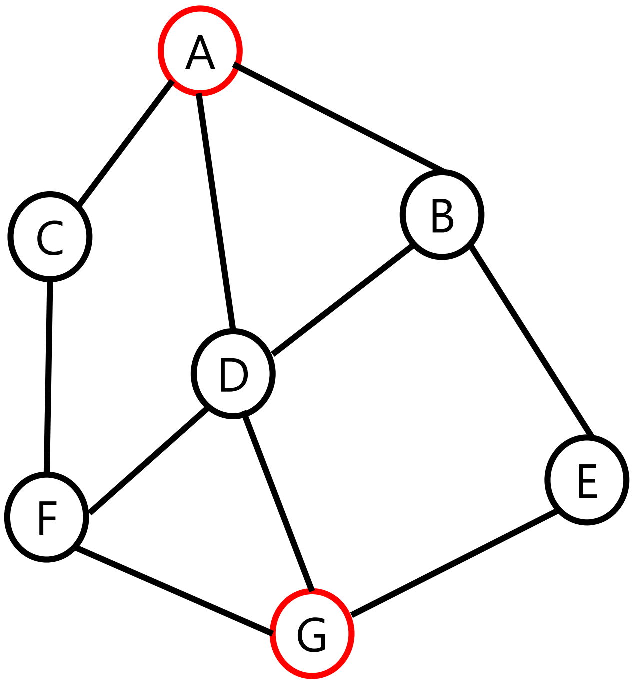


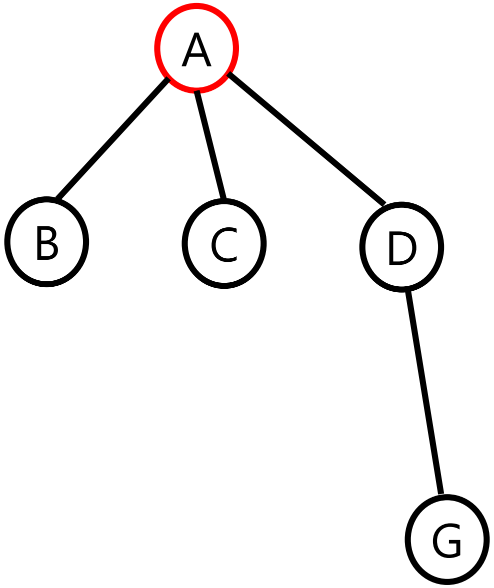


current $\neq$ destination
current $not\ in$ visited

visited = {'A'}
frontier = ['B', 'C', 'D']

Depth-First Search

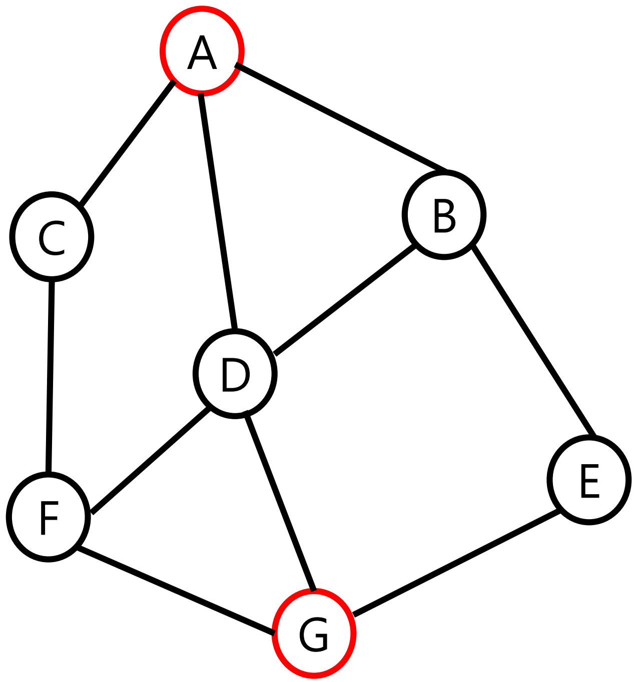


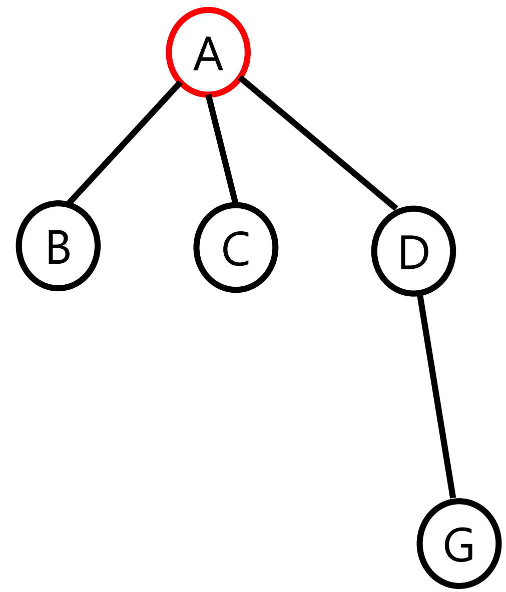


current $\neq$ destination
current $not\ in$ visited

visited = {'A','D'}
frontier = ['B', 'C', 'G']

Depth-First Search





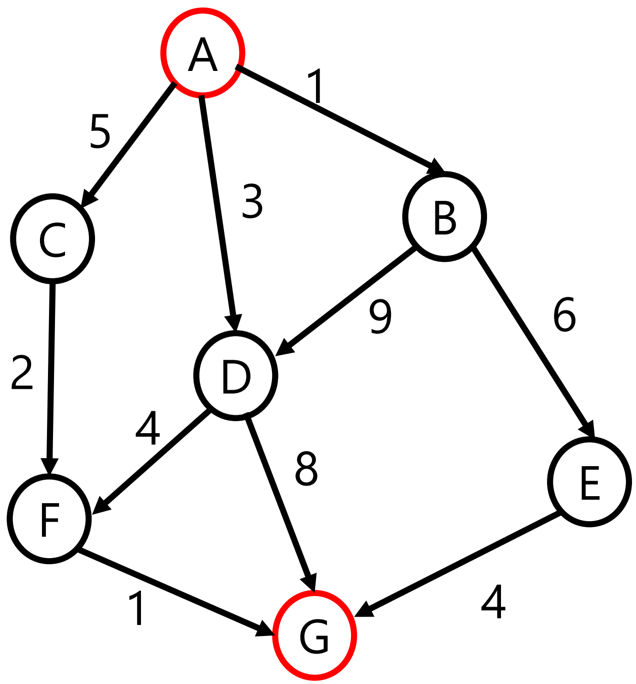
current == destination

Returns $True$

visited = {'A','D'}
frontier = ['B', 'C', 'G']

Weighted Graphs

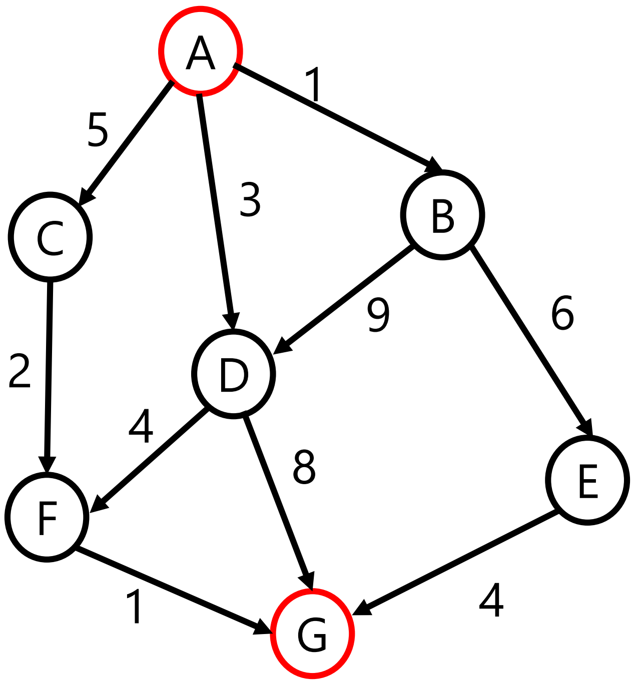
- Objective:
  - Finding distance of shortest path between a source vertex and goal vertex



Directed Acyclic Graph

How to represent the Weighted graph?

- Nested Adjacency Dictionary




```
adjacencyGraph = {'A': {'B':1,'C':5,'D':3},
                  'B' : {'D':9,'E':6},
                  'C' : {'F':2},
                  'D' : {'F':4,'G':8},
                  'E' : {'G':4},
                  'F' : {'G': 1}}
```

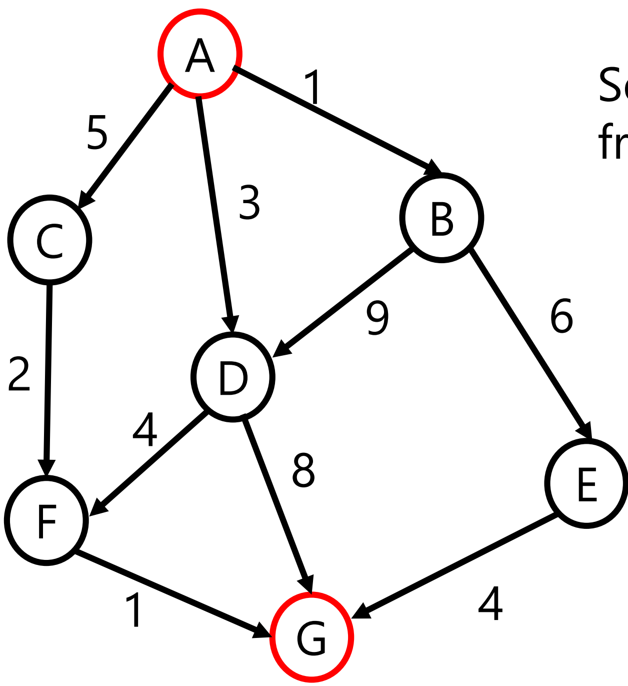
Algorithms

- Exhaustive Search

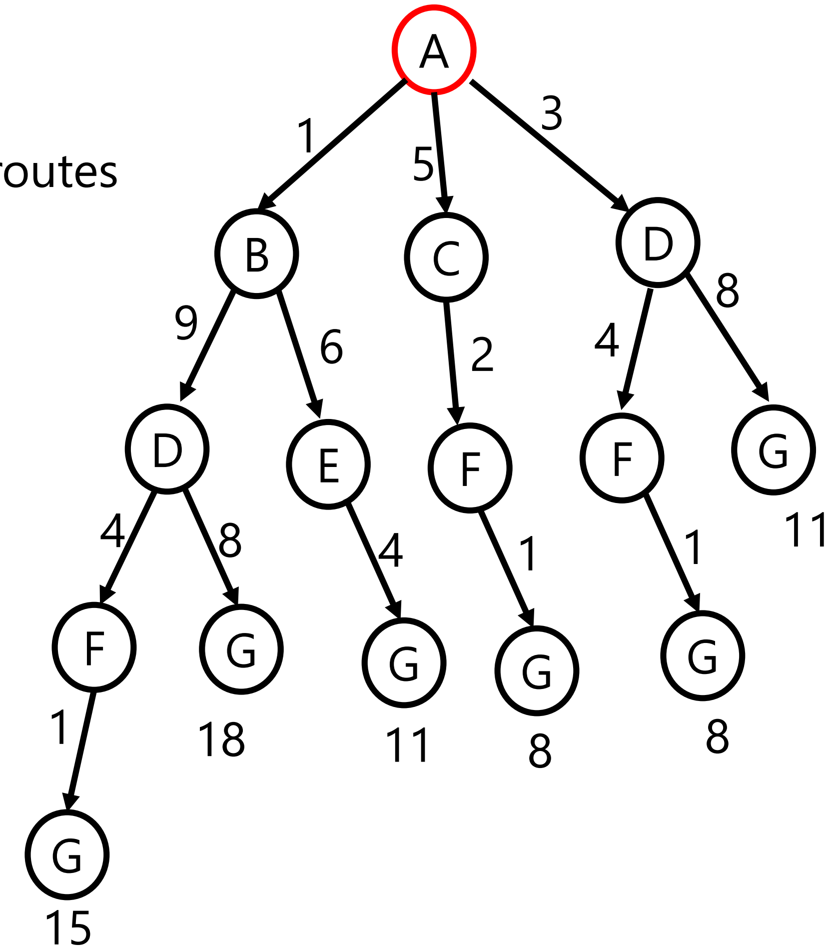
- Dynamic Programming, etc.

- Dijkstra's Algorithm

Exhaustive Search



Search all possible routes
from A to G



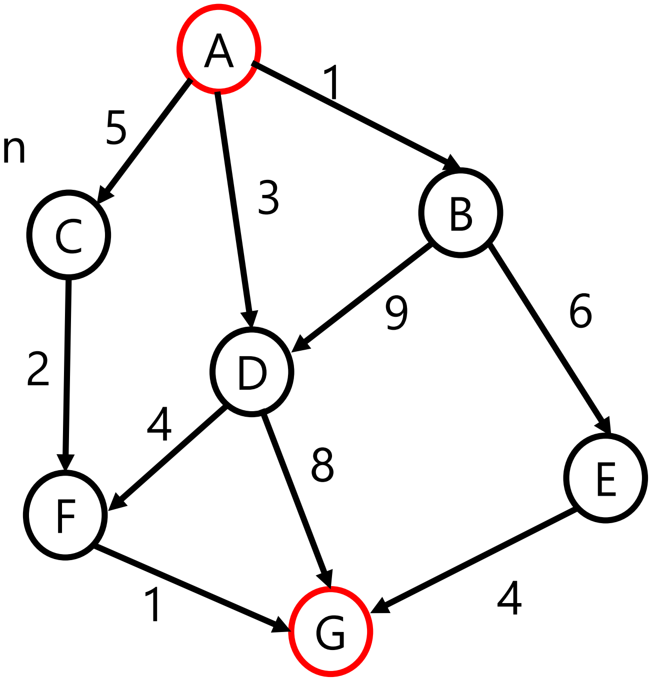
Recursive Algorithm

- Assumption
  - Shortest distance from neighbours of A to G is known

- Shortest distance from A to G is
  - $\min\{d\ (A, v)\ + d(v, G)\}$, $v\ \in \{B, C, D\}$

Distance from A to its neighbour v

Distance from neighbour v to G



- But how do you find distance from neighbour v to G?
  - Repeat the above process, look at its neighbours and select shortest distance to G
  - Till G is found

Shortest Distance between Two Nodes

```
import math
def least_cost(adjDict, source, target):
    def d(vertex):
        if vertex == target:
             return 0
        try:
           return min(adjDict[vertex][i]+d(i) for i in adjDict[vertex])
        except:
           return math.inf

    return d(source)
```

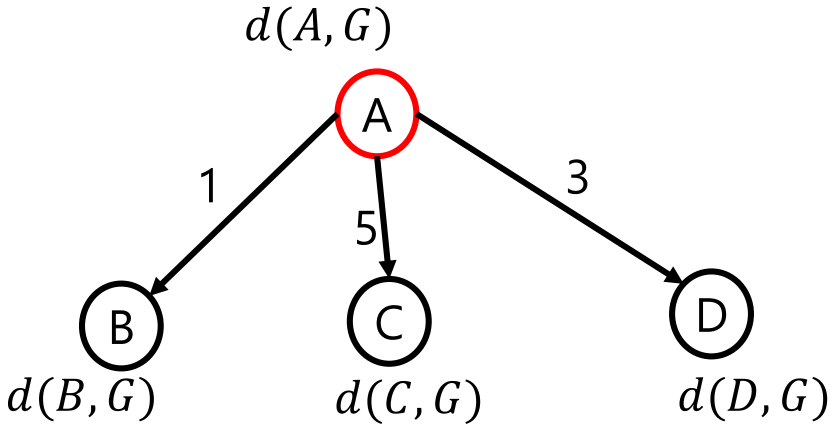
neighbours of vertex

$d\ (A, v)$

obtained from problem

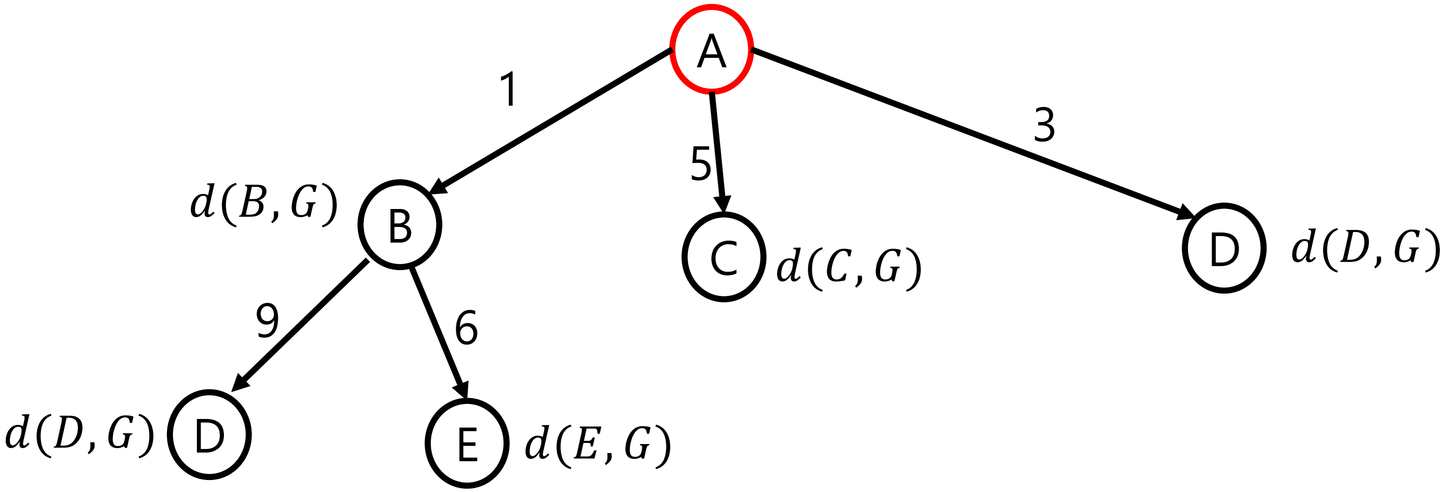
recursive function call $d(v, G)$

Shortest Distance: Recursive Method



$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

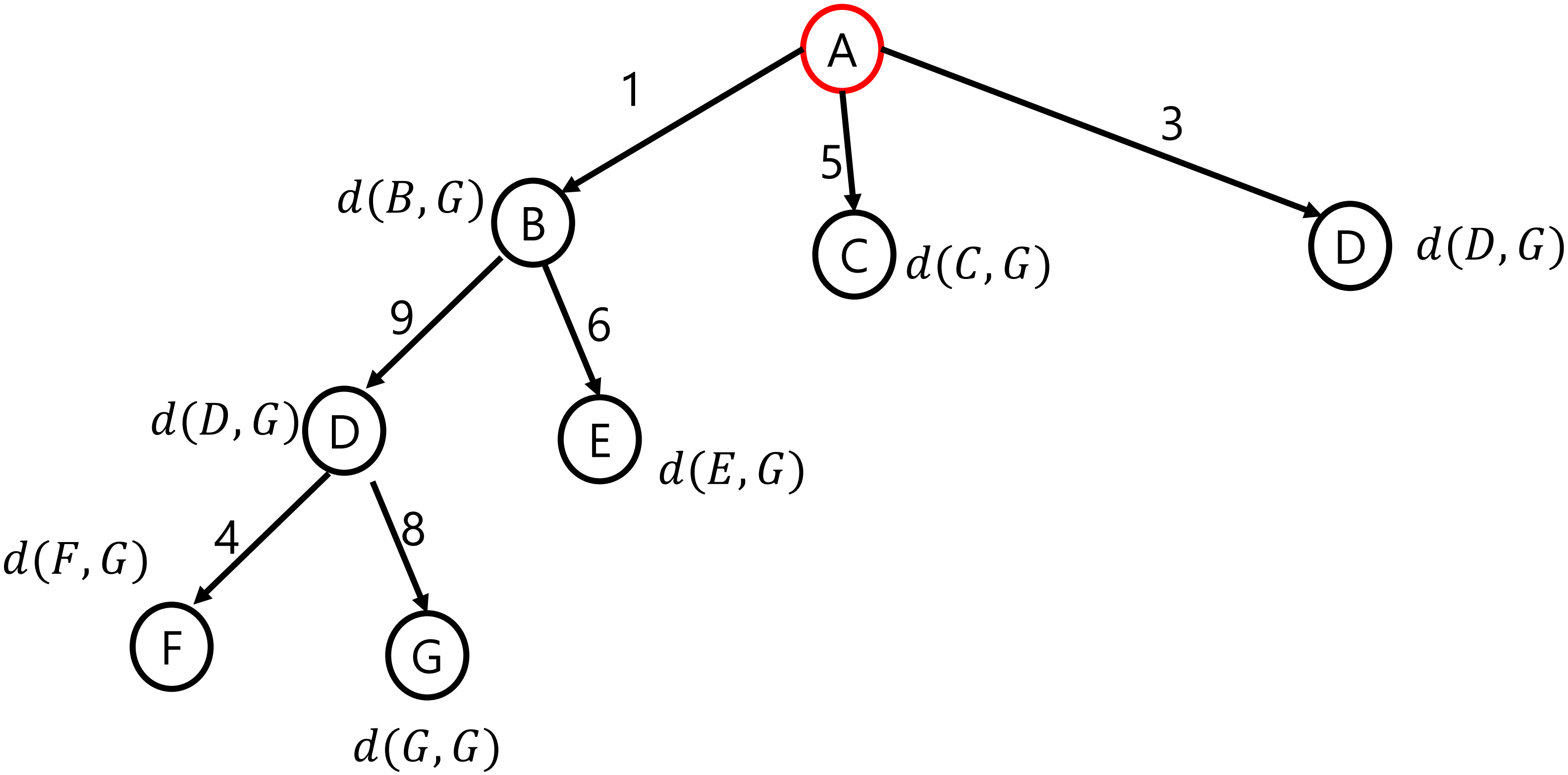
Shortest Distance: Recursive Method



$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(B,G) = \min\{9 + d(D,G), 6 + d(E,G)\}$$

Shortest Distance: Recursive Method

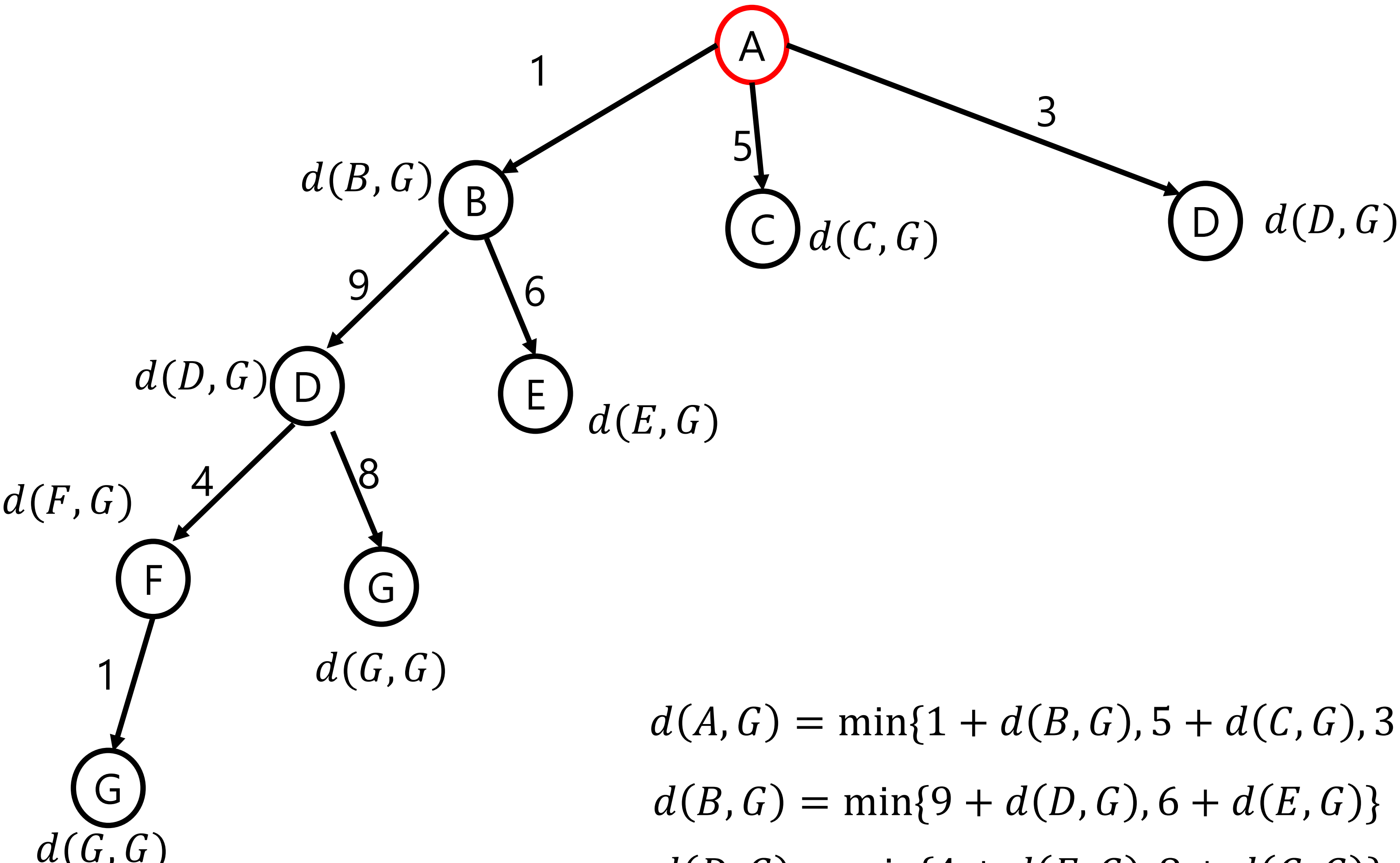


$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(B,G) = \min\{9 + d(D,G), 6 + d(E,G)\}$$

$$d(D,G) = \min\{4 + d(F,G), 8 + d(G,G)\}$$

Shortest Distance: Recursive Method



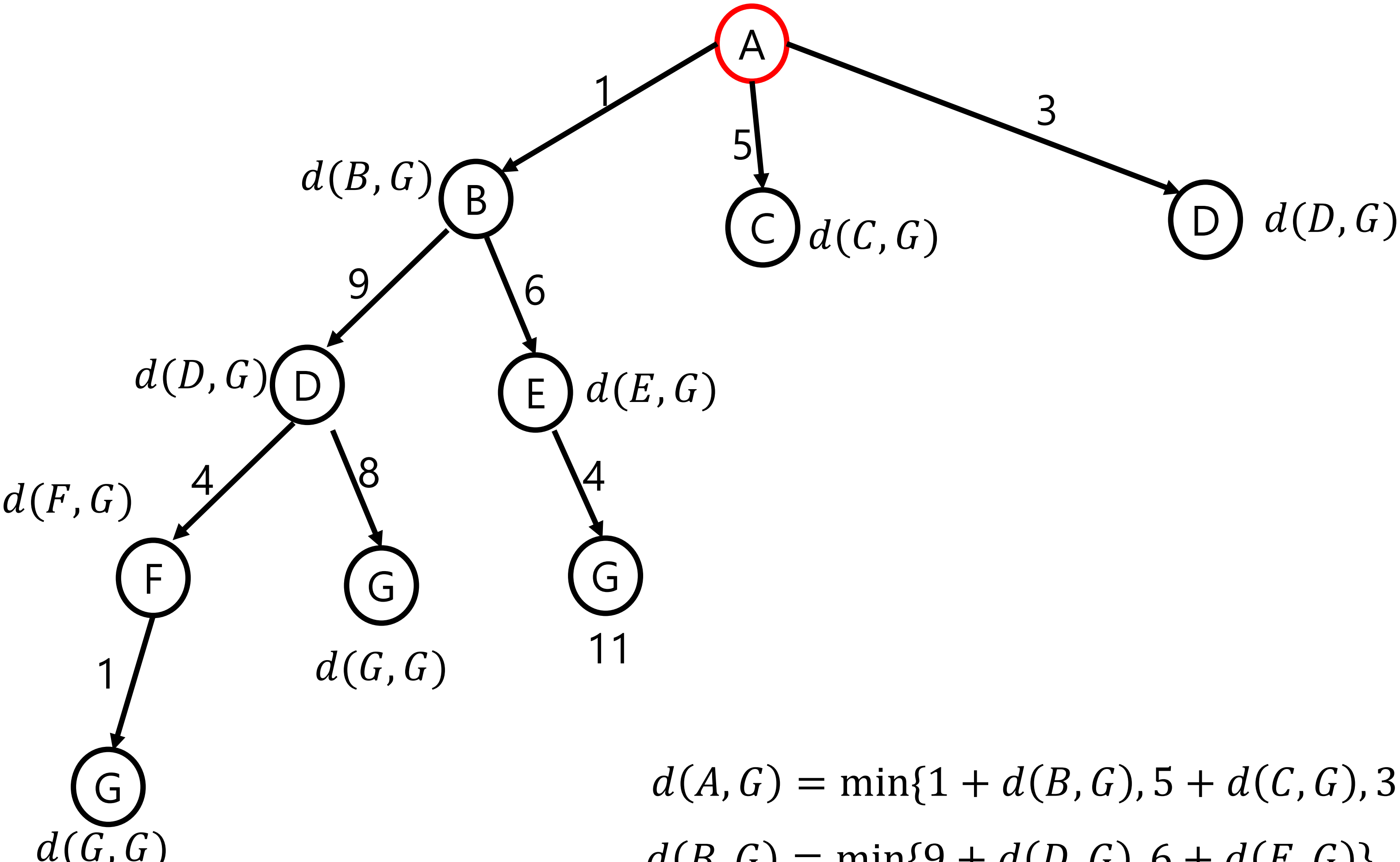
$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(B,G) = \min\{9 + d(D,G), 6 + d(E,G)\}$$

$$d(D,G) = \min\{4 + d(F,G), 8 + d(G,G)\}$$

$$d(F,G) = 1 + d(G,G)$$

Shortest Distance: Recursive Method

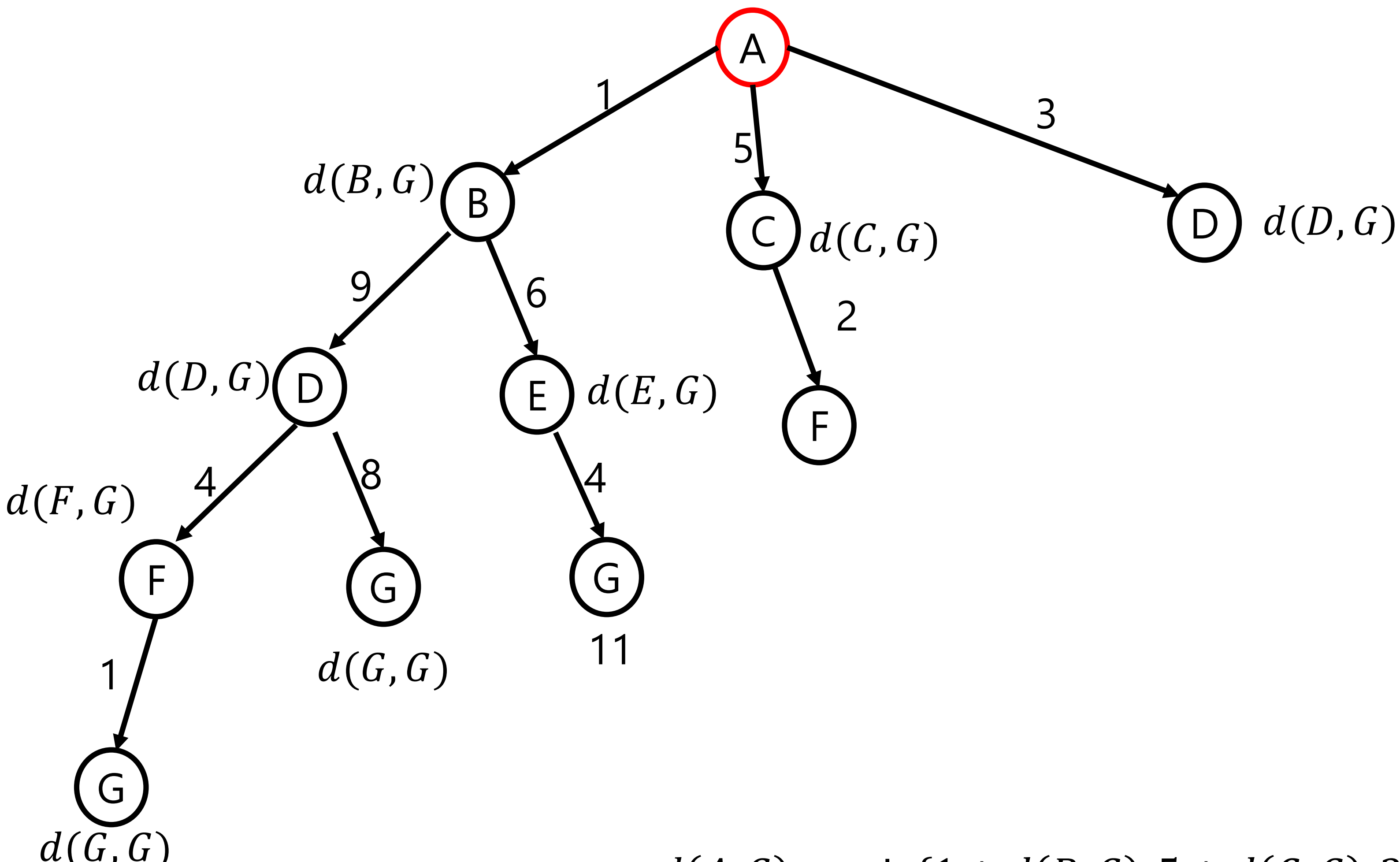


$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(B,G) = \min\{9 + d(D,G), 6 + d(E,G)\}$$

$$d(E,G) = 4 + d(G,G)$$

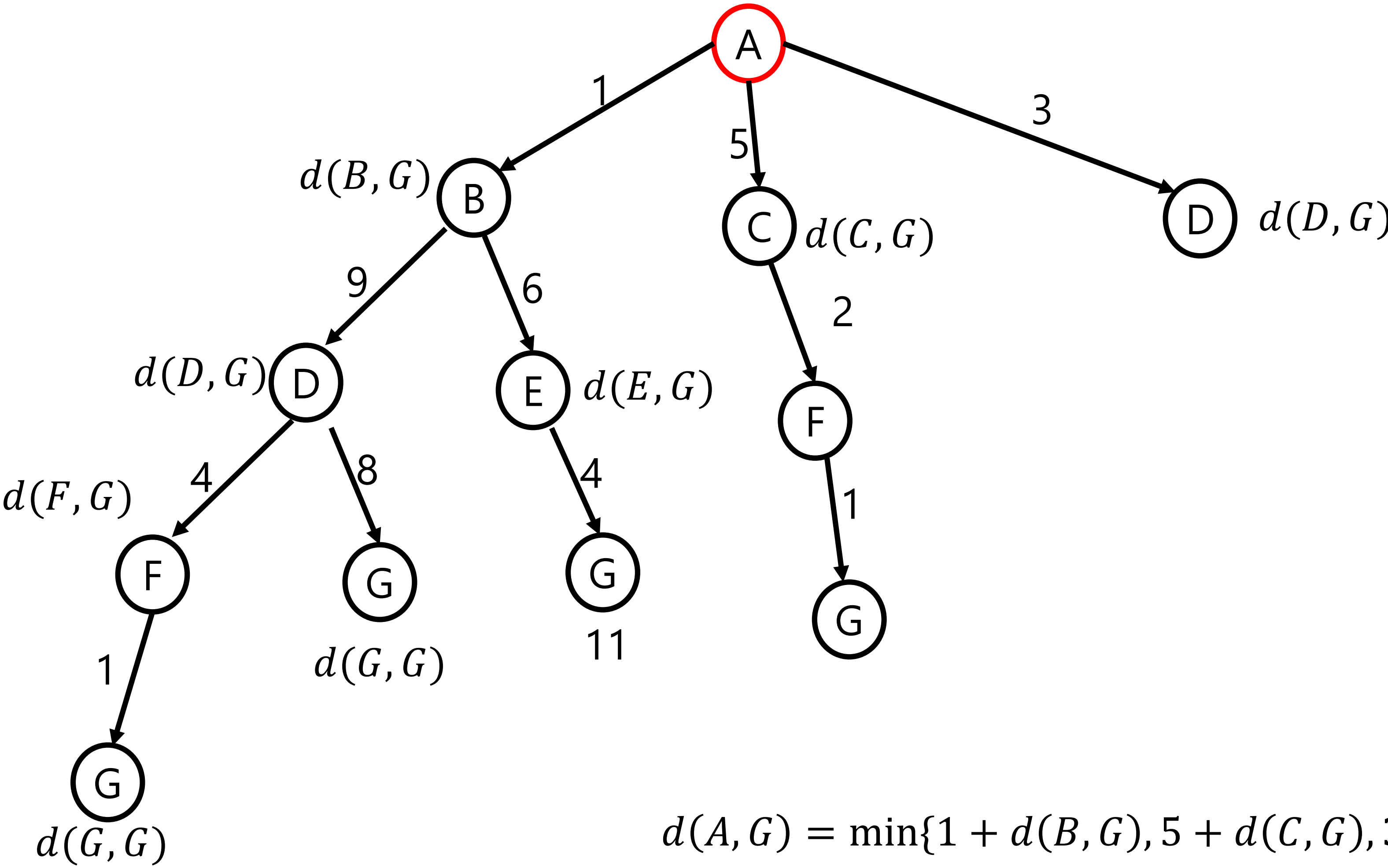
Shortest Distance: Recursive Method



$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(C,G) = 2 + d(F,G)$$

Shortest Distance: Recursive Method

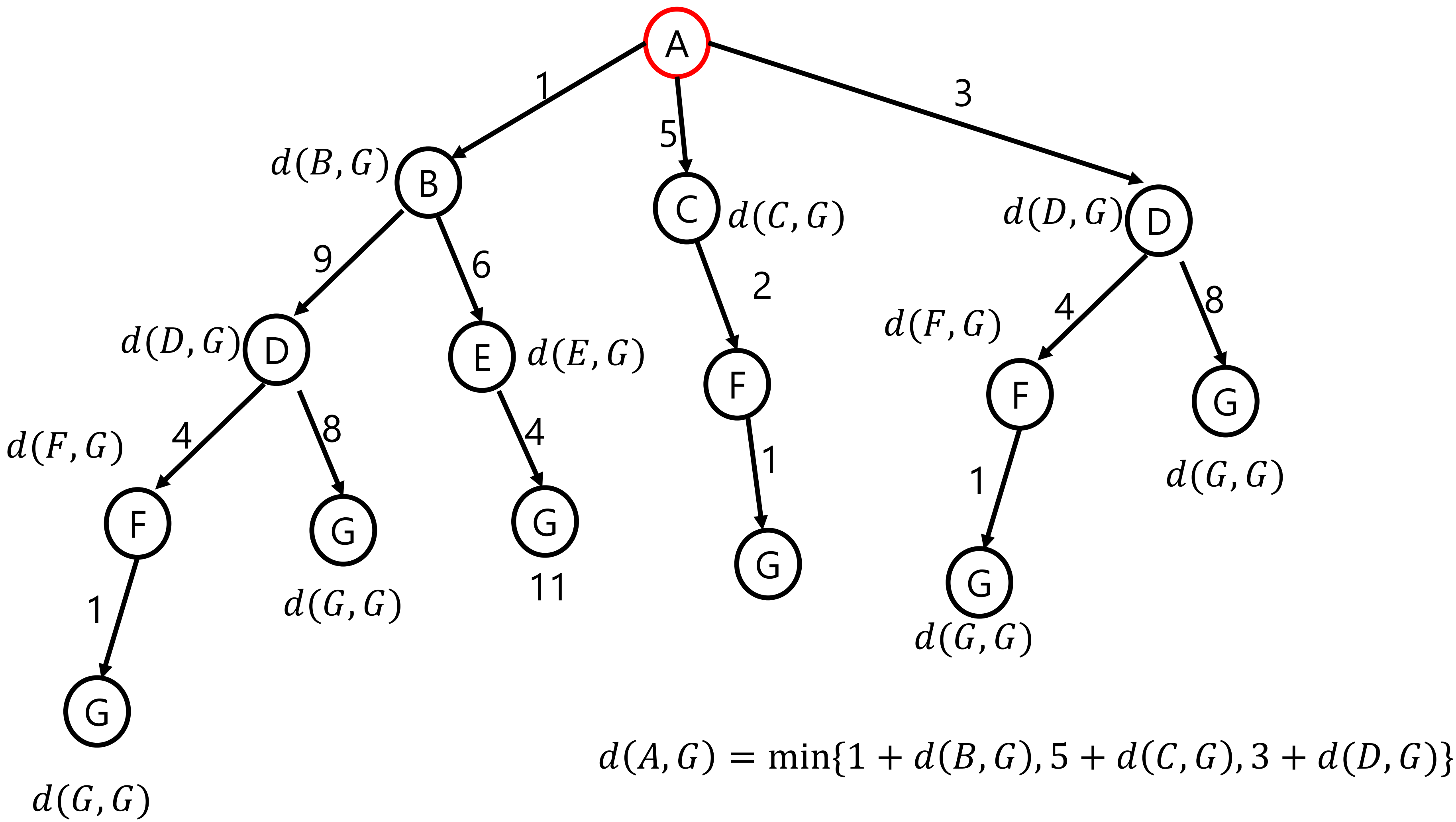


$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

$$d(C,G) = 2 + d(F,G)$$

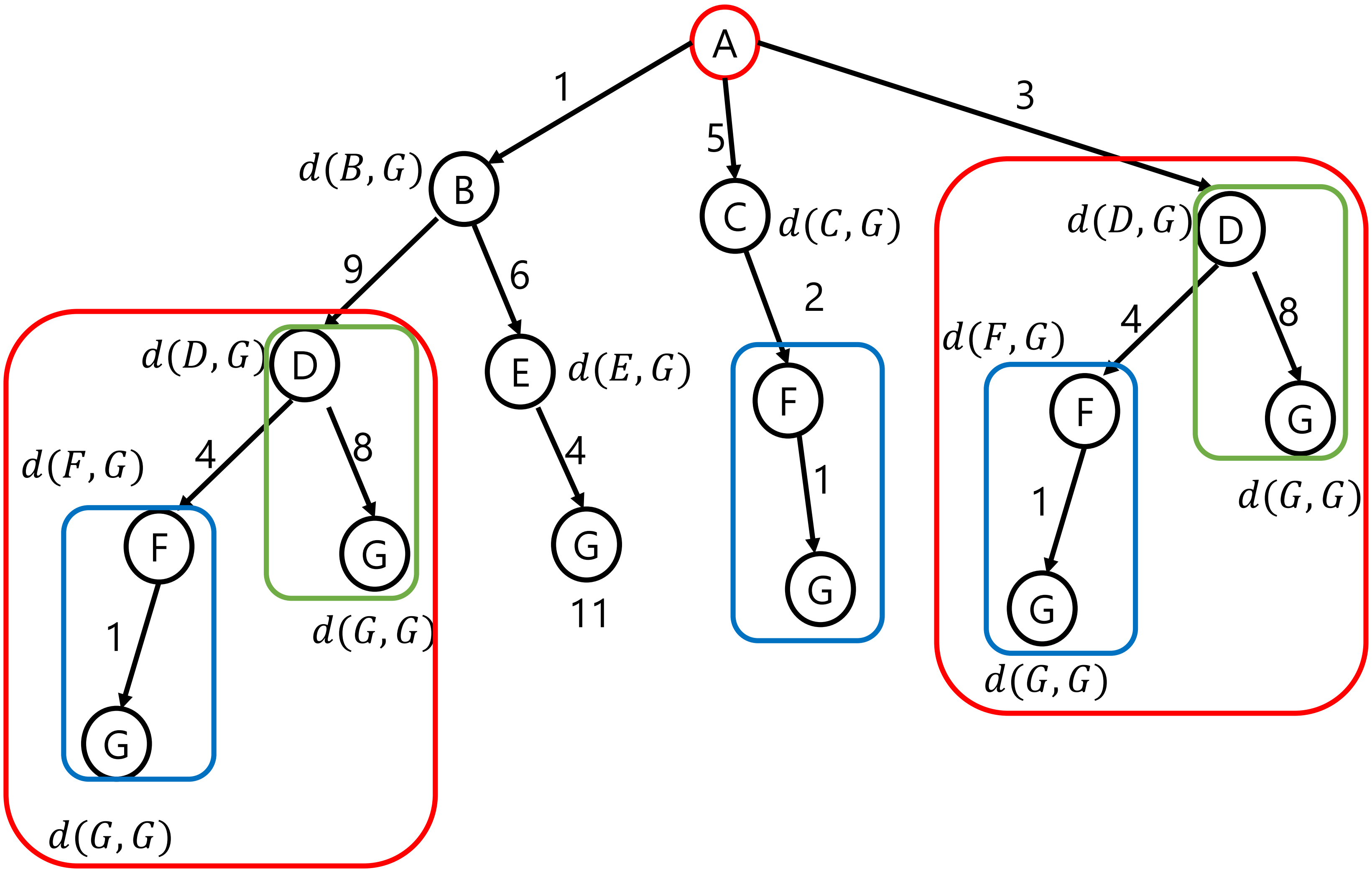
$$d(F,G) = 1 + d(G,G)$$

Shortest Distance: Recursive Method



$$d(A,G) = \min\{1 + d(B,G), 5 + d(C,G), 3 + d(D,G)\}$$

Shortest Distance: Recursive Method



Shortest Distance: Memoized Recursive Version

```
import math
def least_cost(adjDict, source, target):
    @cache
    def d(vertex):
        if vertex == target:
            return 0
        try:
            return min(adjDict[vertex][i]+d(i) for i in adjDict[vertex])
        except:
            return math.inf

    return d(source)

print(least_cost(adjDict, 'A', 'G'))
```

Summary

- Dynamic Programming
  - General Problem Solving
    - Divide-and-conquer with redundant or overlapping subproblems
  - Optimization
    - Solving problems that have overlapping subproblems with optimal solutions
    - Subproblem dependency should be acyclic (i.e., only for DAGs)
  - Python's decorators simplifies memoization in DP