Dijkstra's Algorithm to find Shortest Paths from a Source to all

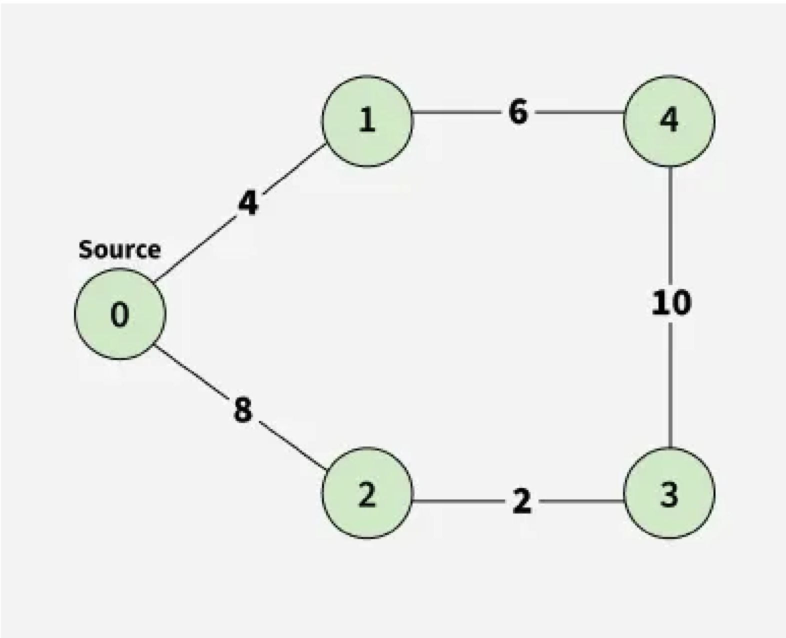
Last Updated : 23 Jul, 2025

Given a weighted undirected graph represented as an **edge** list and a source vertex `src`, find the shortest path distances from the source vertex to all other vertices in the graph. The graph contains **V** vertices, numbered from `0` to `V - 1`.

Note: The given graph does not contain any negative edge.

Examples:

> ***Input:*** *src = 0, V = 5, edges[][] = [[0, 1, 4], [0, 2, 8], [1, 4, 6], [2, 3, 2], [3, 4, 10]]*



Graph with 5 node

> ***Output:*** *0 4 8 10 10*
> ***Explanation:*** *Shortest Paths:*
> *0 to 1 = 4. 0 → 1*
> *0 to 2 = 8. 0 → 2*
> *0 to 3 = 10. 0 → 2 → 3*
> *0 to 4 = 10. 0 → 1 → 4*

Dijkstra's Algorithm using Min Heap - O(E*logV) Time and O(V) Space

> *In Dijkstra's Algorithm, the goal is to find the shortest distance from a given source node to all other nodes in the graph. As the source node is the starting point, its distance is initialized to zero. From there, we iteratively pick the unprocessed node with the minimum distance from the source, this is where a min-heap (priority queue) or a set is typically used for efficiency. For each picked node u, we update the distance to its neighbors v using the formula:* ***dist[v] = dist[u] + weight[u][v],*** *but only if this new path offers a shorter distance than the current known one. This process continues until all nodes have been processed.*

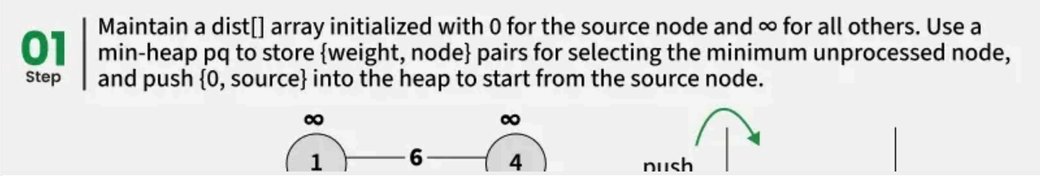
Step-by-Step Implementation

1. Set dist[source]=0 and all other distances as infinity.
2. Push the source node into the min heap as a pair <distance, node> → i.e., <0, source>.
3. Pop the top element (node with the smallest distance) from the min heap.
    1. For each adjacent neighbor of the current node:
    2. Calculate the distance using the formula:

       dist[v] = dist[u] + weight[u][v]

       If this new distance is shorter than the current dist[v], update it.
       Push the updated pair <dist[v], v> into the min heap
4. **Repeat** step 3 until the min heap is empty.
5. Return the distance array, which holds the shortest distance from the source to all nodes.

Illustration:



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```python
# Returns shortest distances from src to all other vertices
def dijkstra(V, edges, src):
    # Create adjacency list
    adj = constructAdj(edges, V)

    # Create a priority queue to store vertices that
    # are being preprocessed.
    pq = []

    # Create a list for distances and initialize all
    # distances as infinite
    dist = [sys.maxsize] * V

    # Insert source itself in priority queue and initialize
    # its distance as 0.
    heapq.heappush(pq, [0, src])
    dist[src] = 0

    # Looping till priority queue becomes empty (or all
    # distances are not finalized)
    while pq:
        # The first vertex in pair is the minimum distance
        # vertex, extract it from priority queue.
        u = heapq.heappop(pq)[1]

        # Get all adjacent of u.
        for x in adj[u]:
            # Get vertex label and weight of current
            # adjacent of u.
            v, weight = x[0], x[1]

            # If there is shorter path to v through u.
            if dist[v] > dist[u] + weight:
                # Updating distance of v
```

```
                dist[v] = dist[u] + weight
                heapq.heappush(pq, [dist[v], v])

    # Return the shortest distance array
    return dist
```

Output

```
0 4 8 10 10
```

Time Complexity: O(E*logV), Where E is the number of edges and V is the number of vertices.
Auxiliary Space: O(V), Where V is the number of vertices, We do not count the adjacency list in auxiliary space as it is necessary for representing the input graph.

Problems based on Shortest Path

- Shortest Path in Directed Acyclic Graph
- Shortest path with one curved edge in an undirected Graph
- Minimum Cost Path
- Path with smallest difference between consecutive cells
- Print negative weight cycle in a Directed Graph
- 1st to Kth shortest path lengths in given Graph
- Shortest path in a Binary Maze
- Minimum steps to reach target by a Knight
- Number of ways to reach at destination in shortest time
- Snake and Ladder Problem
- Word Ladder

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