```python
class NetworkRoutingSolver:
    def __init__( self ):
        pass

    def initializeNetwork( self, network ):
        assert( type(network) == CS312Graph )
        self.network = network

    def getShortestPath( self, dest_index ):
        self.dest = dest_index

        # TODO: RETURN THE SHORTEST PATH FOR destIndex
        #       INSTEAD OF THE DUMMY SET OF EDGES BELOW
        #       IT'S JUST AN EXAMPLE OF THE FORMAT YOU'LL
        #       NEED TO USE

        path_edges = []
        total_length = 0

        # Setting total length and edges to return for the destination index
        # Takes O(n) time and O(n) space to build an array
        self.current_index = self.queue.nodes[self.dest]
        while True:
            if self.current_index.node_id == self.source:
                break
            current_loc = self.current_index.loc
            previous = self.queue.get_previous(self.current_index)
            if previous is None:
                break
            weight = self.queue.get_previous_weight(self.current_index)
            path_edges.append((current_loc, previous.loc,
'{:.0f}'.format(weight)))
            self.current_index = self.queue.get_previous(self.current_index)
            total_length = total_length + weight

        return {'cost': total_length, 'path': path_edges}

    def computeShortestPaths( self, srcIndex, use_heap=False ):
        self.source = srcIndex
        t1 = time.time()

        # To check if user wants to use binary heap or unsorted array
        if use_heap:
            self.queue = BinHeap(self.network, srcIndex)
        else:
            self.queue = Unsorted_Array(self.network, srcIndex)

        # Implementation of Dijkstra's Algorithm
        # The overall algorithm would take O((V+E)logV) time for the heap
implementation and O(V^2) time for the array.
        # For both implementations, the space complexity would be O(V) since they
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both use array to store the weights
        # of every node.
        while not self.queue.isEmpty():
            u = self.queue.delMin()
            if u == -1:
                break
            if u.node_id != 0:
                self.queue.building_queue(u)
            adjacents = u.neighbors
            for i in range(0, len(adjacents)):
                if self.queue.get_weight(adjacents[i].dest) >
self.queue.get_weight(u) + adjacents[i].length:
                    self.queue.set_weight(adjacents[i].dest,
self.queue.get_weight(u) + adjacents[i].length)
                    self.queue.set_previous(adjacents[i].dest, u)
        t2 = time.time()
        return t2-t1

# Implementation of unsorted array
class Unsorted_Array:
    def __init__(self, graph, src):
        self.graph = graph
        self.nodes = graph.getNodes()
        self.node_weight = [sys.maxsize - 1] * len(self.nodes)
        self.previous_node = [None] * len(self.nodes)
        self.deletedNodes = []
        self.unsorted_array = []
        self.unsorted_array.append(CS312GraphEdge(self.nodes[src],
self.nodes[src], 0))
        self.node_weight[src] = 0
        self.previous_node[src] = self.nodes[src]
        self.building_queue(self.nodes[src])

    # Making a queue takes O(n) time for array
    def building_queue(self, node):
        for i in range(0,len(node.neighbors)):
            if node.neighbors[i].dest.node_id not in self.deletedNodes:
                self.unsorted_array.append(node.neighbors[i])

    # Takes O(n) time and space complexity
    def delMin(self):
        temp = sys.maxsize
        this_node = -1
        index = -1
        for i in range(len(self.unsorted_array)):
            if self.node_weight[self.unsorted_array[i].dest.node_id] < temp and \
                    self.unsorted_array[i].dest.node_id not in self.deletedNodes:
                temp = self.node_weight[self.unsorted_array[i].dest.node_id]
                this_node = self.unsorted_array[i].dest.node_id
                index = i
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        if this_node == -1:
            return -1
        else:
            retVal = self.unsorted_array[index].dest
            self.deletedNodes.append(retVal.node_id)
            self.unsorted_array.pop(index)
            return retVal


    # return false if the queue is not empty
    def isEmpty(self):
        if len(self.unsorted_array) > 0:
            return False
        return True

    # O(n) Helper functions
    def set_previous(self, node, prev_node):
        self.previous_node[node.node_id] = prev_node.node_id

    def set_weight(self, node, distance):
        self.node_weight[node.node_id] = distance

    def get_previous(self, node):
        if self.previous_node[node.node_id] is not None:
            return self.nodes[self.previous_node[node.node_id]]

    def get_weight(self, node):
        return self.node_weight[node.node_id]

    def get_previous_weight(self, node):
        if self.previous_node[node.node_id] is not None:
            return self.node_weight[node.node_id] -
self.node_weight[self.previous_node[node.node_id]]
        return 0



# Implementation of binary heap data structure
class BinHeap:
    def __init__(self, graph, srcIndex):
        self.nodes = graph.nodes
        self.currentSize = 0
        self.heapList = []
        self.insert(CS312GraphEdge(self.nodes[srcIndex], self.nodes[srcIndex],
0))

        self.node_weight = [sys.maxsize - 1] * len(self.nodes)
        self.previous_node = [None] * len(self.nodes)

        self.deletedNodes = list()
        self.node_weight[srcIndex] = 0
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        self.previous_node[srcIndex] = self.nodes[srcIndex]

        self.building_queue(self.nodes[srcIndex])

    # Making a heap takes O(nlog n) time and O(n) space complexity because
inserting a node in the middle may require
    # O(n) operations to shift the rest
    def building_queue(self, node):
        for i in range(len(node.neighbors)):
            if node.neighbors[i].dest.node_id not in self.deletedNodes:
                self.insert(node.neighbors[i])
                self.bubbleUp(self.currentSize - 1)

    def insert(self, u):
        self.heapList.append(u)
        self.currentSize += 1

    # This part takes O(log n) time and O(n) space to maintain the heap property
    # Dividing the index by 2 gives the parent node
    def bubbleUp(self, i):
        while i // 2 > 0:
            if self.node_weight[self.heapList[i].dest.node_id] <
self.node_weight[self.heapList[i // 2].dest.node_id]:
                temp = self.heapList[i // 2]
                self.heapList[i // 2] = self.heapList[i]
                self.heapList[i] = temp
            i = i // 2

    # The smallest should go to the top of the tree to maintain the heap property
    # Takes O(log n) time and O(n) space complexity
    def delMin(self):
        if self.isEmpty():
            return -1
        retVal = self.heapList[0].dest
        self.heapList[0] = self.heapList[-1]
        self.deletedNodes.append(retVal.node_id)
        self.currentSize = self.currentSize - 1
        self.heapList.pop()
        self.trickle_down(0)
        return retVal

    # This part takes O(log n) time and O(n) space complexity
    def trickle_down(self, i):
        if not self.isEmpty():
            while i * 2 <= self.currentSize:
                minimumChild = self.minChild(i)
                if minimumChild == -1:
                    break
                if self.node_weight[self.heapList[i].dest.node_id] >
self.node_weight[self.heapList[minimumChild].dest.node_id]:
                    temp = self.heapList[i]
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                    self.heapList[i] = self.heapList[minimumChild]
                    self.heapList[minimumChild] = temp
                i = minimumChild

    def minChild(self, i):
        if i * 2 + 1 >= self.currentSize:
            return -1
        elif i * 2 + 2 >= self.currentSize:
            return i * 2 + 1
        else:
            if self.node_weight[self.heapList[i*2+1].dest.node_id] <
self.node_weight[self.heapList[i*2+2].dest.node_id]:
                return i*2+1
            else:
                return i*2+2

    # return false if the queue is not empty
    def isEmpty(self):
        if self.currentSize > 0:
            return False
        return True

    # O(n) Helper functions
    def get_weight(self, node):
        return self.node_weight[node.node_id]

    def get_previous(self, node):
        if self.previous_node[node.node_id] is not None:
            return self.nodes[self.previous_node[node.node_id]]

    def get_previous_weight(self, node):
        if self.previous_node[node.node_id] is not None:
            return self.node_weight[node.node_id] -
self.node_weight[self.previous_node[node.node_id]]
        return 0

    def set_weight(self, node, distance):
        self.node_weight[node.node_id] = distance

    def set_previous(self, node, prev_node):
        self.previous_node[node.node_id] = prev_node.node_id
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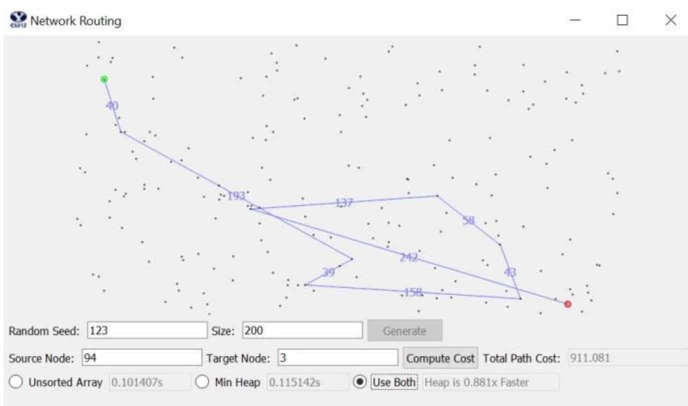
3. The overall time complexity for binary heap would be O((V+E)logV) because there is one making queue, and V times of deleting the minimum, and E times of decreasing key and each takes O(nlogn), O(logn), and O(logn). For space complexity, it would be O(n) since it's using arrays to store the needed data.

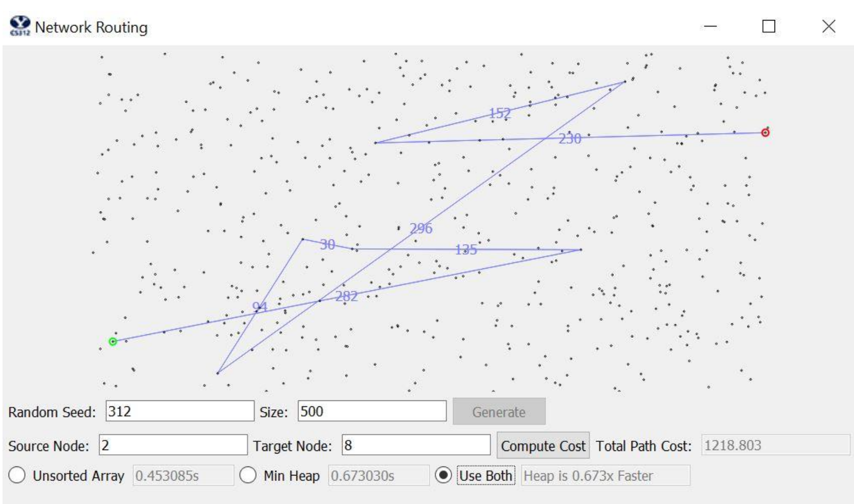
The overall time complexity for unsorted array would be O(V^2 + E). We know each nodes has 3 neighbors, so it can be denoted as O(V^2). Like the heap implementation, it takes one making queue, V times of deleting the minimum, and E times of decreasing the key, which take O(n), O(n), O(1) times each. Also, its space complexity is O(n) since it uses arrays to store and keep track of the data.

4. A - was not reachable

B -



C -



5.		1	2	3	4	5	Average
100	Heap	0.13	0.06	0.15	0.07	0.17	0.12
	Array	0.02	0.02	0.03	0.02	0.02	0.02
1000	Heap	1.19	1.77	1.48	1.82	2.06	1.67
	Array	2.69	2.34	2.46	2.6	2.62	2.54
10000	Heap	68.6	70.2	68.01	67.08	68.42	68.46
	Array	couldn't figure out					

It seems the code takes particularly long to find the shortest paths and I couldn't really create the whole table.