Urban Bus Route Planning Using Reverse Labeling Dijkstra Algorithm for Temporal Network

Akanksha Sachan[1], Dr Kumar Gaurav[2]

[1]M.tech Scholar, Dept. Of Electronics Engineering, HBTU, Uttar Pradesh, India
[2]Assistant Professor, Dept. Of Electronics Engineering, HBTU, Uttar Pradesh, India

---

Abstract— *One of the significant challenges in path optimization is unpredictability of traffic patterns. Route Planning is the process of finding the best possible path to reach the destination while considering various factors such as distance, traffic, road condition, and other constraints. Effective route planning is critical for optimizing travel time, reducing fuel consumption, and improving overall transportation efficiency. The existing algorithms mostly considers waiting time at particular node and distance between two node to find the route. They generally do not consider the demand or traffic congestion toward next node. The demand or traffic congestion value differs for both the incoming and outgoing road. To resolve this issue we have applied Reverse Labeling Dijkstra Algorithm, which find the optimum route between source destination pair considering traffic congestion or demand.*

***Keywords*—RLDA, Arc Attribute, Edge Attribute, Route Planning**

1. INTRODUCTION

Route Planning in urban cities is a crucial aspect of modern transportation planning. With the growth of urbanization, there has been a significant increase in traffic volume, leading to traffic congestion, safety concerns, and environmental pollution. Route planning aims to address these challenges by providing most efficient and safe routes for vehicles and pedestrian to travel in urban areas. To improve the road's traffic conditions, it is important to perform research on the Intelligent Transportation System (ITS).

ITS refers to the comprehensive system designed to achieve greater traffic control, modern information integration, electronic technology for communication and other high-tech goods [1]. ITS uses real-time data and communication networks to collect, process, and disseminate information about traffic conditions, weather, road infrastructure, and other relevant factors that affect transportation. The application of contemporary communication technologies, management skills, and analytical abilities like big data, cloud computing, and artificial intelligence is the most crucial integration of the transportation industry to realise the real-time traffic condition. It improves the current state of urban traffic for people, ensuring travel safety for people. [2, 3].

DRGS (Dynamic Route Guidance System), which utilizes the latest technologies such as GPS (Global Positioning System), computers, and telecommunications, to obtain more time and traffic information on the network and provide the driver with an optimal driving route, is an important component. This way of smart transportation is used to improve urban traffic conditions. The feature of this system is based on the road data and includes elements all of which are traffic, people, vehicle, roads. It leads to increase in the profits of the drivers, and proper distribution of city traffic.

In the current path optimization research, time spent in the arc is usually calculated and the time spent on the node is typically ascribed to or ignored for the related arc. There are numerous intersections and road segments within the city's road network. The time taken at the junction will also be longer than the time to cross the street due to the effects of traffic lights and regulations, as well as the fact that vehicles travelling straight, sideways, turning right, turning left, or turning from a U-intersection have different driving patterns. Therefore when planning routes for city traffic, one must take into account the time to cross road and intersection at the same time.

2. LITERATURE REVIEW

The shortest path method and intelligent optimization algorithm are the two most commonly utilized optimization algorithms in DRGS. [4]. The shortest path algorithm: Dijkstra Algorithm [5,6], A* Algorithm[7], Flyod algorithm and other heuristic search algorithm. Intelligent Optimisation algorithm includes: Particle Swarm Optimisation Algorithm, Ant Colony Optimisation algorithm, Genetic Algorithm, neural network algorithm, etc.The shortest path problem was initially addressed by Dijkstra's method in 1959. This strategy is typically used to resolve the single source shortest path problem. The Dijkstra algorithm has a temporal complexity of O(n2) [8].

Liu et al. further enhanced the Dijkstra algorithm to address the issue of poor availability by carefully examining the characteristics and limitations of the route and traffic capacity [9]. Raphael et al. first presented the A* method as one of the shortest path optimizations in 1968 [10]. The shortest path in the network of static roads can be found most effectively using the direct heuristic search algorithm, A* Algorithm.

In order to solve combinatorial optimization issues like the travelling salesman problem (TSP), secondary allocation problem (QAP), job scheduling problem (JSP), and other combinatorial optimization issues, ant colony optimization (ACO) is frequently used. ACO has the advantages of parallelism, robustness, and positive feedback. The ant colony algorithm will enter the local optimum when solving the problem of route planning because of the enormous number of crossings and roads in metropolitan networks. It also has issues with a large number of iterations and temporal complexity.

An enhanced evolutionary method for the Capacitated Vehicle Routing Problem (CVRP) was proposed by Mohammed et al., Yang suggested combining the Particle Swarm Optimisation (PSO) method with a genetic algorithm (GA). [11], An approach that combines particle swarm optimization (PSO) and ant colony optimization (ACO) was proposed by Chen et al. [12]. With regard to Vehicle Routing Problem with Time Window (VRPTW), An enhanced particle swarm optimization technique was put forth by Yang et al. [13]. For the purpose of solving the VRPTW issue, Zhang et al. suggested a novel discrete Particle Swarm Optimisation method. Based on the above study there have been various optimization techniques to solve the problem of route planning

3. PROBLEM STATEMENT

In this article, we examine how to plan traffic routes in a deterministic network while taking junction time consumption into account. Travel time along an arc and the amount of time between nodes with various next arcs are both changeable in this network.

Urban bus routing system faces challenges in optimizing routes and ensuring efficient transportation. The existing bus routing system relies on predefined routes that do not consider real-time traffic condition, resulting in suboptimal routes and increased travel time. Traditional bus routing algorithms often fails to adapt to changing demand pattern, variation in passenger preference, or unforeseen disruption. This lack of flexibility results in flexible routes that do not cater to evolving transportation needs, leading to inefficiencies and decreased passenger satisfaction.

By leveraging the Reverse Labeling Dijkstra Algorithm (RLDA), the urban bus routing system can overcome these challenges and improve efficiency, passenger satisfaction, and overall urban transportation. Arc attribute represents the traffic congestion of the road.

4. MATHEMATICAL MODEL

To represent the road network, we take into consideration a directed weighted graph G = (V,E, Ω,Φ) with four tuples:

E: Set of all segment between intersections in road network (arc in network).

V: Set of all intersection in the network (nodes).

(i, j): i and j are connected by an edge.

Ω :Set of the edge attribute value, L(i,j) is the attribute value for the specific edge, or the amount of time it takes a vehicle to pass that specific edge.

Φ: Set of arc attribute value for the directed graph of particular node, The arc attribute value for the specific arc, i.e. traffic congestion in that specific arc, is given by Λ(i,j,k).

The mathematical model of the problem can be described as:

$$\Gamma(S,D) = \min_{(j_0,\dots\dots,j_{n-1},j_n)} \sum_{k=1}^{n} [L(j_{k-1},j_k) + \Lambda(j_{k-1},j_k,j_{k+1})] \quad (1)$$

Where, Γ(S, D) denotes the minimum travel from source to destination.

5. RLDA ALGORITHM

A Dijkstra algorithm variant called the Reverse Labeling Dijkstra Algorithm is used to determine the shortest route between a source and a destination. Starting at the destination node, the algorithm moves backwards towards the source node, updating the node labels as it goes

6. STEPS OF RLDA

Step 1: Set the label of all the nodes in the graph.

Step 2: Sort all the arc on the basis of its attribute.

Step 3: Check the source node in sorted list of arcs.

Step 4: If source node is found add arc in the path
Jump to Step 6.

Step 5: If source node is not found then select the arc
with minimum travel time and jump to Step 1 .

Step 6: Calculate the total cost of the final path.

7. SIMULATION STEPS

In this part, the Reverse Labeling Dijkstra Algorithm (RLDA) is simulated to find the best route in a real-time road network. We perform RLDA algorithm in Python Language in AnacondaNavigator. The code is run on JupyterNotebook in AnacondaNavigator on an Intel(R)

Core(TM) i5-7200U processor at 2.50GHz with 12GB RAM on a Windows 10 64-bits operating system.

8. SIMULATION

In this section we shall validate Reverse Labeling Dijkstra Algorithm (RLDA) using a directed graph. Let us consider a directed graph (fig 1) having 11 nodes and 18 directed arcs.

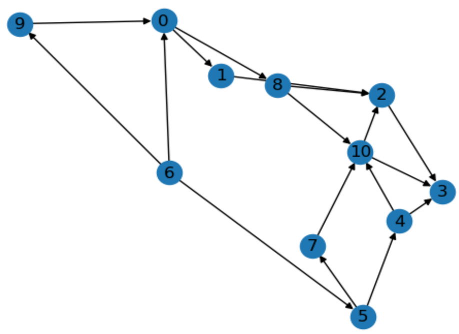

Fig -1: Directed graph

Time spent on each edge is given by edge attribute value L(i,j) is shown in Table 1.

Travel time of each road segment is arc attribute Λ(i,j,k) is shown in Table 2.

The destination node is 3, and the source node is 6. The motive behind the algorithm is to find the minimum time path from source node 6 to destination node 3.

Table -1: Edge Attribute Values

S.No.	Edge	Edge attribute values
1	(6,0)	3
2	(6,5)	4
3	(6,9)	4
4	(0,1)	3
5	(0,8)	3
6	(9,0)	3
7	(9,7)	4
8	(5,7)	5
9	(5,4)	6
10	(1,2)	3
11	(8,2)	4
12	(8,10)	3
13	(7,10)	5
14	(4,10)	6
15	(4,3)	6
16	(2,3)	7
17	(10,2)	5
18	(10,3)	6

When considering only the edge attributes value the path followed for source node to destination node is
6 ⟶ 0 ⟶ 8 ⟶ 10 ⟶ 3, according Dijkstra Algorithm and the travel time is 15.
When arc attribute value is considered, using RLDA, the route followed will be
6 ⟶ 0 ⟶ 1 ⟶ 2 ⟶ 3 and travel time will be 23.

To further verify the algorithm we have applied the same algorithm to a network with 42 nodes and 72 edges. The network is shown in fig 2.The degree of the

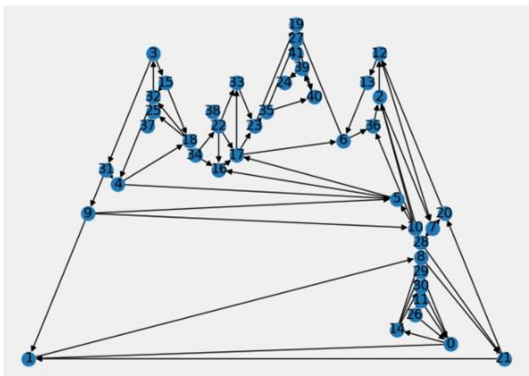

Fig -2: Network Graph

Table -2: Arc Attribute Values

S. No.	Arc	Arc attribute value
1	(6,0,1)	2
2	(6,0,8)	4
3	(6,9,0)	2
4	(6,9,7)	3
5	(6,5,7)	4
6	(6,5,4)	3
7	(0,1,2)	2
8	(0,8,2)	4
9	(0,8,10)	4
10	(9,0,1)	3
11	(9,0,8)	2
12	(9,7,10)	5
13	(5,7,10)	3
14	(5,4,10)	3
15	(5,4,3)	4
16	(1,2,3)	3
17	(8,2,3)	3
18	(8,10,2)	4
19	(8,10,3)	5
20	(7,10,2)	5
21	(7,10,3)	4
22	(4,10,2)	4
23	(4,10,3)	3
24	(10,2,3)	2

given network is shown in fig 3.The traffic congestion for the given network is shown in fig 4.

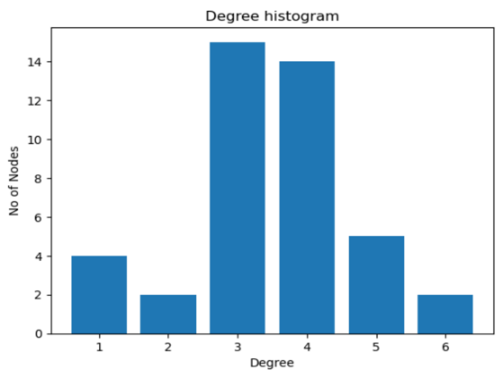

Fig -3: Degree Distribution

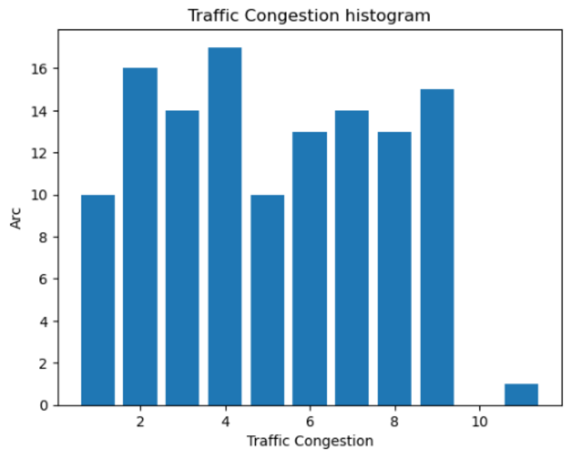

Fig -4: Traffic congestion distribution of network

9. RESULTS

The simulation method is all carried out for the same source destination pair. In this condition, we will observe the various outcomes in the path obtained by both the algorithms : (1) RLDA; (2) Dijkstra Algorithm. For each source destination pair we shall calculate its edge attribute value and arc attribute value.

After conducting the simulation following outcomes are been observed:

(1) After simulation we have observed the path obtained in both algorithms differs.

(2) The number of nodes found in path obtained via RLDA algorithm was more than that in Dijkstra Algorithm. This result can been seen when we plot the graph for different combination of source destination pair. The plot is shown in fig 5.

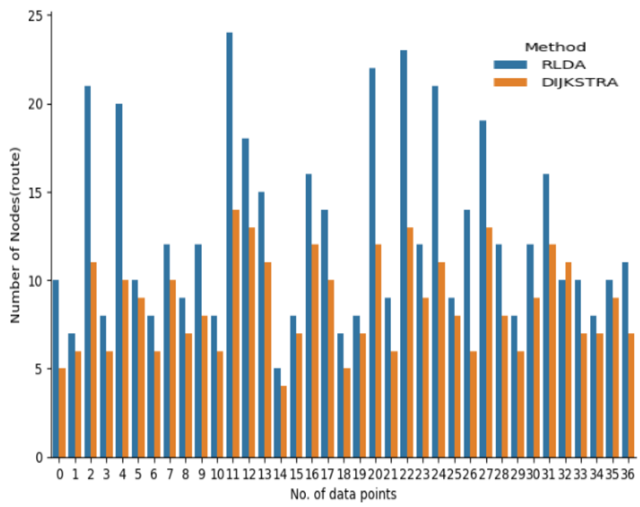

Fig -5: Comparison of number of nodes found in RLDA and Dijkstra

In the above plot no. of data points represents the various source destination pair.

(3) The total edge attribute values of RLDA Algorithm are much more as compared to Dijkstra Algorithm. This result can been seen when we plot the graph for different combination of source destination pair. The plot is shown in fig 6.

(4) The total arc attribute values of RLDA Algorithm are much more as compared to Dijkstra Algorithm. This result can been seen when we plot the graph for different combination of source destination pair. The plot is shown in fig 7.

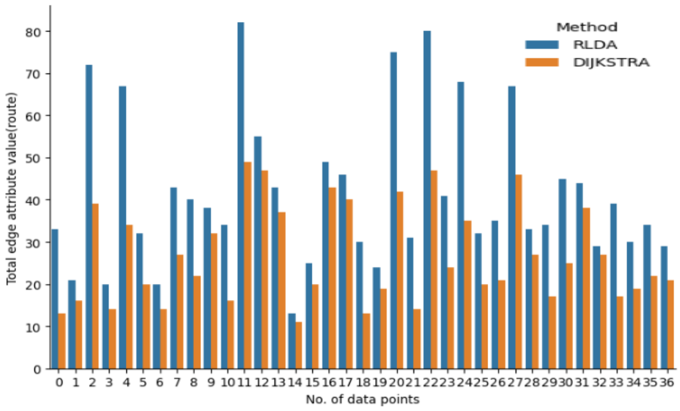

Fig -6: Comparison of edge attribute values found in RLDA and Dijkstra

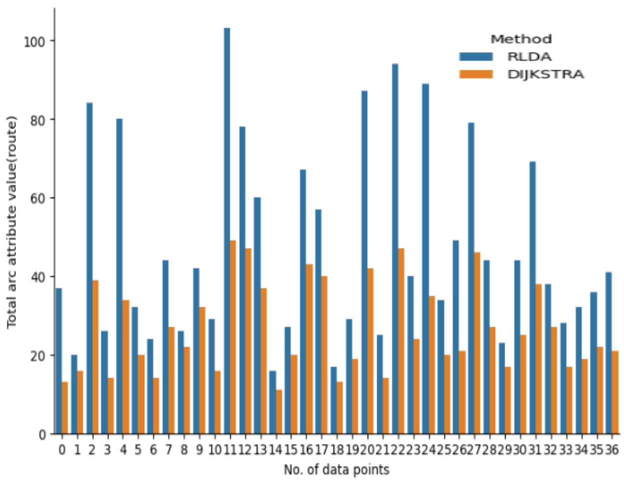

Fig -7: Comparison of arc attributes found in RLDA and Dijkstra

(5) The distance obtained in RLDA covers much more nodes than that in Dijkstra, from this we can also conclude that the services provided to people in the path covered using RLDA Algorithm are more in number as compared to that of Dijkstra Algorithm. This comparison is shown in fig 8.

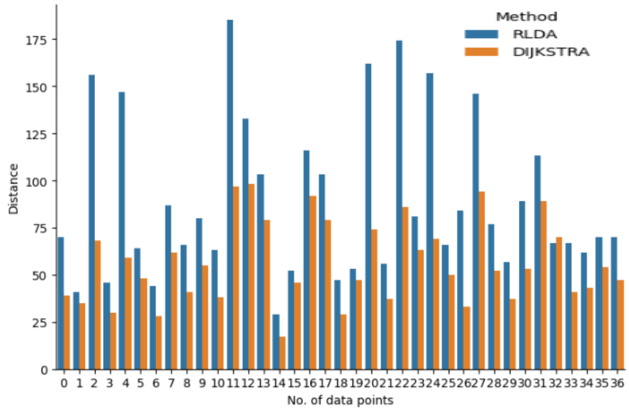

Fig -8: Comparison of total distance found in RLDA and Dijkstra

10. RESULTS

In urban bus route planning, the objective is to determine efficient routes for buses to serve a set of stops or station, taking into account factors such as passenger demand, travel time, distance, and operational constraints. The results obtained shows that Reverse Labeling Dijkstra Algorithm proves beneficial in this context. The final route obtained by Reverse Labeling Dijkstra Algorithm at a particular instant of time covers maximum nodes, which means it provide services to the maximum number of people. The results show that it provide better results as compared to the Dijkstra Algorithm as number of nodes covered by Dijkstra Algorithm are less compared to the Reverse Labeling Dijkstra Algorithm. Passenger satisfaction is also prioritized through RLDA. By incorporating passenger preferences into the routing algorithm, it ensures that routes are designed to meet individual needs, minimize transfer time, and provide convenient transportation options. This personalized approach enhances the overall passenger experience and encourages more people to choose public transportation as a reliable and efficient mode of transport.

REFERENCES

[1] B. W. Yang, "Research status and development trend analysis of intelligent transportation system," China Plant Engineering, vol. 2, pp. 121-122, 2019.

[2] Q. T. Geng, Study on the Key Technology of Intelligent Transportation System Based on the Theory of Image Recognition, Jilin University, Changchun, China, 2016.

[3] B. Wei, Modeling and Simulation Research on Vehicular Ad Hoc Networks of Intelligent Transportation System Based on Internet of Things, Lanzhou Jiaotong University, Lanzhou,China, 2017.

[4] P. Liu, "Research on modeling and optimization algorithm of dynamic route guidance system in intelligent transportation system," Ph.D. dissertation, Dept. Auto. Eng., Jilin Univ., Changchun, China, 2017.

[5] E. W. Dijkstra, "A note on two problems in connection with graphs,''Numerische Math., vol. 1, no. 1, pp. 171_269, 1959.

[6] Y. L. Chen, L. Y. Zhuang, L. B. Zhu, X. J. Shao, and H. Wang, "Research n path planning of parking system based on the improved Dijkstra algorithm, "Modern Manuf. Eng., vol. 6, no. 7, pp. 63_67, 2017.

[7] Y. W. Liu and H. Q. Wu, "Path planning based on theoretical shortest distance variable weight A* algorithm,'' Comput. Meas. Control, vol. 26,no. 4, pp. 175_178, 2018.

[8] Wang Shu-xi and Wu Zhengxue, "Improved Dijkstra Shortest Path Algorithm and its Application," vol. 39, no. 5, pp. 223–228, Jan. 2012.

[9] Y. L. Liu, Y. Li, J. L. Wu, and X. Meng, "Route planning of expressway emergency evacuation based on improved Dijkstra algorithm,'' Transp. Res., vol. 2, no. 6, pp. 54_66, 2016.

[10] P. Hart, N. Nilsson, and B. Raphael, "A Formal Basis for the Heuristic Determination of Minimum Cost Paths," *IEEE Transactions on Systems Science and Cybernetics*, vol. 4, no. 2, pp. 100–107, 1968.

[11] W. Y. Zhi, "Improved GA with particle swarm's evolutionary strategy for solving constrained optimization problems,'' Control Decis., vol. 16, no. 4, pp. 135_147, 2012.

[12] Y. Kao, M.-H. Chen, and Y.-T. Huang, "A Hybrid Algorithm Based on ACO and PSO for Capacitated Vehicle Routing Problems," vol. 2012, pp. 1–17, Aug. 2012.

[13] Y. F. Ma, F. Yan, and K. Kang, "An improved particle swarm optimization for simultaneous pickup and delivery vehicle routing problems with time wdows under a fuzzy random environment," Oper Res. Manage. Sci.,vol. 27, no. 12, pp. 73_83, 2018.

[14] D.-D. Zhu and J.-Q. Sun, "A New Algorithm Based on Dijkstra for Vehicle Path Planning Considering Intersection Attribute," *IEEE Access*, vol. 9, pp. 19761–19775, 2021.