ITC-CSCC 2023

The 38th International Technical Conference on Circuits/Systems, Computers, and Communications 2023

Jeju, Republic of Korea

Paper ID 1570904012

Deep Reinforcement Learning Based Bus Stop-Skipping Strategy

Authors: Mau-Luen Tham, Bee-Sim Tay, Kok-Chin Khor, Somnuk Phon-Amnuaisuk

Presenter: Mau-Luen THAM

ASEAN IVO

UTAR UNIVERSITI TUNKU ABDUL RAHMAN

Wholly owned by UTAR Education Foundation
(Co. No. 578227-M)
DU012(A)

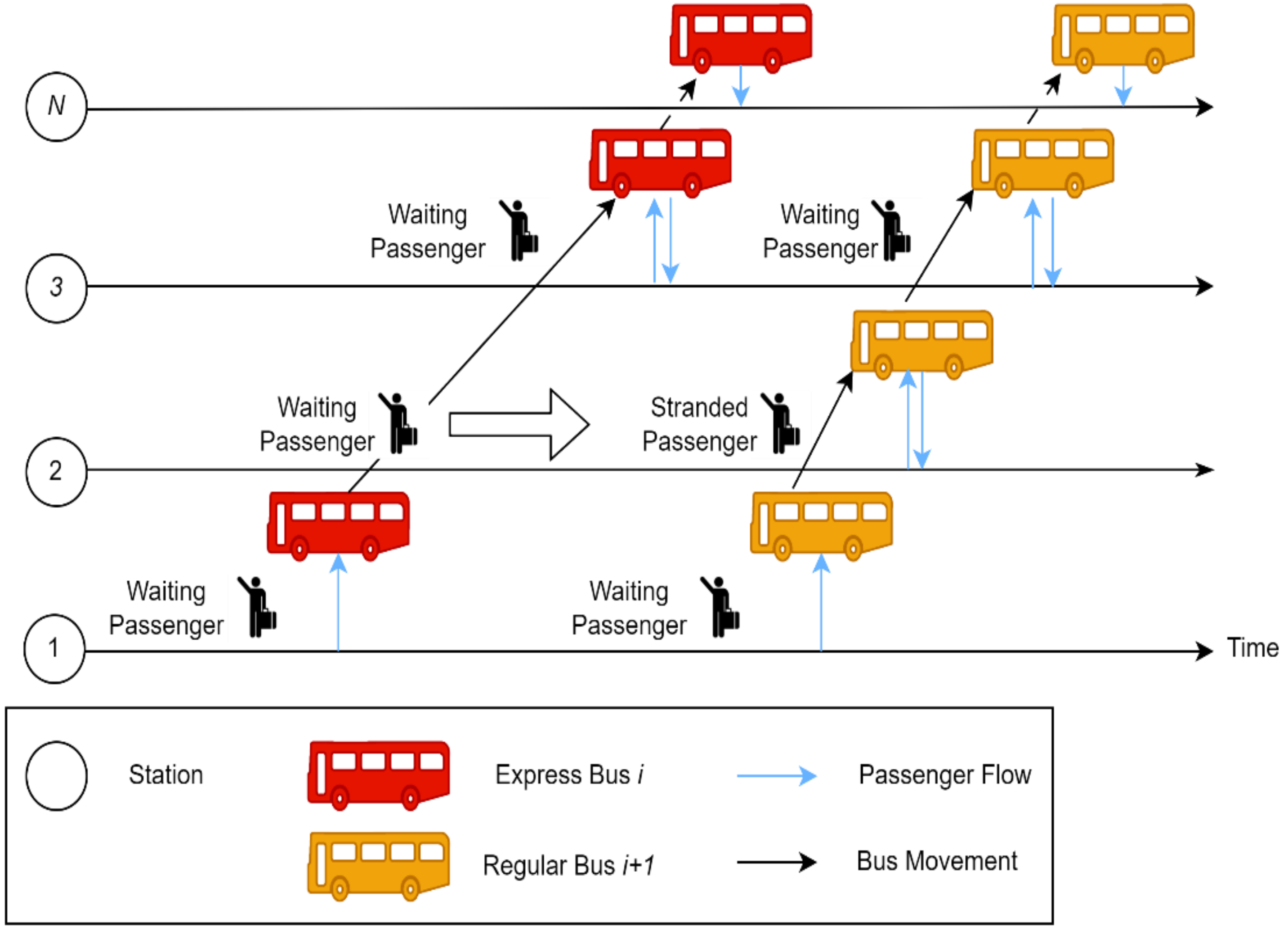
UNIVERSITI TEKNOLOGI BRUNEI 1986

Introduction

- Static routes cannot accommodate the ever-increasing mobility needs of huge populations [1].
- Stop-skipping strategy is one of the popular public transport route optimization methods [3].

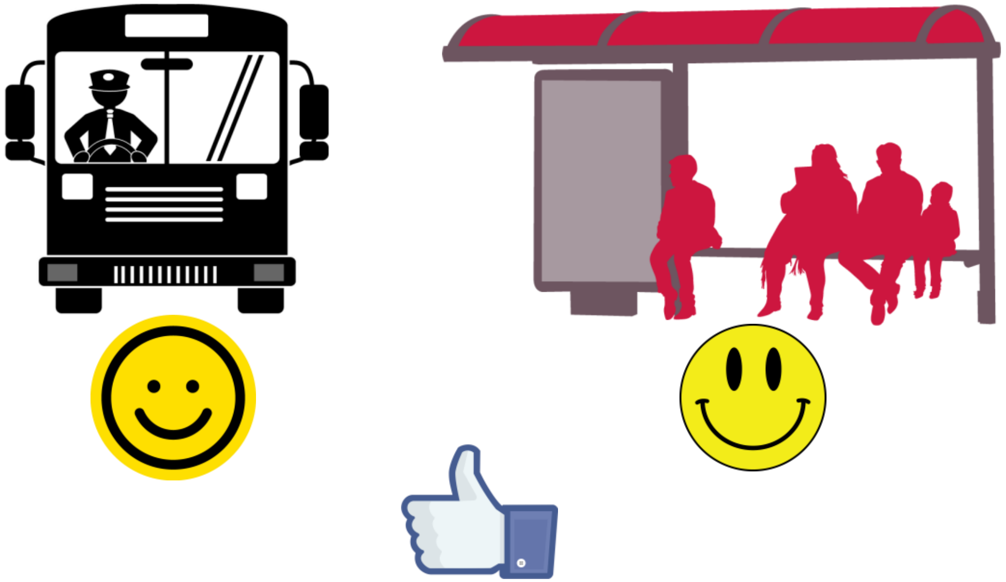
Bus Stop-Skipping Strategy (1 Express and 1 No-Skip)

The bus stop-skipping scheme starts with express bus *i* and is followed by a no-skip bus *i+1*.



ITC-CSCC 2023

Problem Statement



Optimal tradeoff can be achieved under deterministic scenarios (e.g. history traffic conditions and passenger demands)

Limitation: Cannot adapt to real-time conditions (e.g. traffic congestion level).

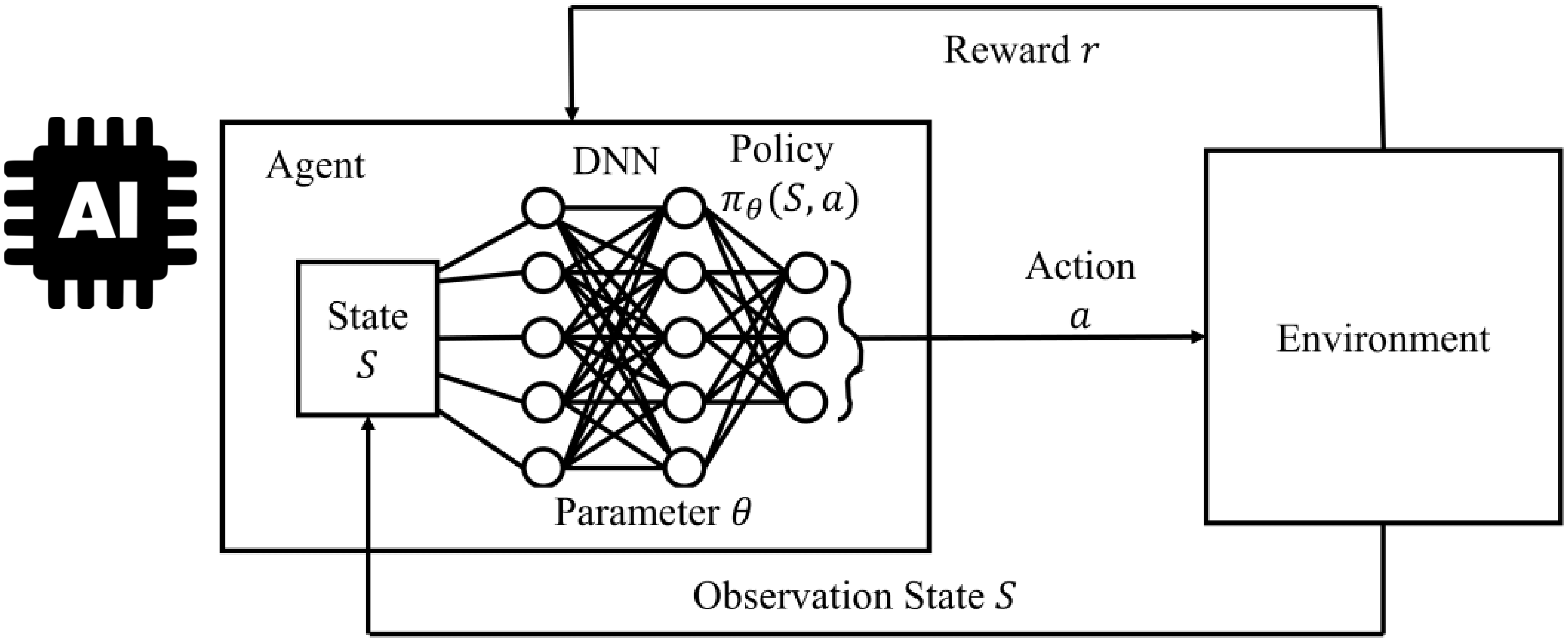
Related Work (Nonlinear Programming)

- In [5], the authors formulated the stop-skipping issue as a nonlinear 0-1 stochastic programming problem. However, they neglected the operating cost incurred by the bus operators.
- To reach an optimal tradeoff between both operators and passengers, the work in [6] formulated another nonlinear integer programming problem. However, the solution was found via a brute-force approach.
- **Limitation**: These works focuses on solving the bus optimization problems by assuming fixed travel time.

Related Work (Bio-inspired Algorithm)

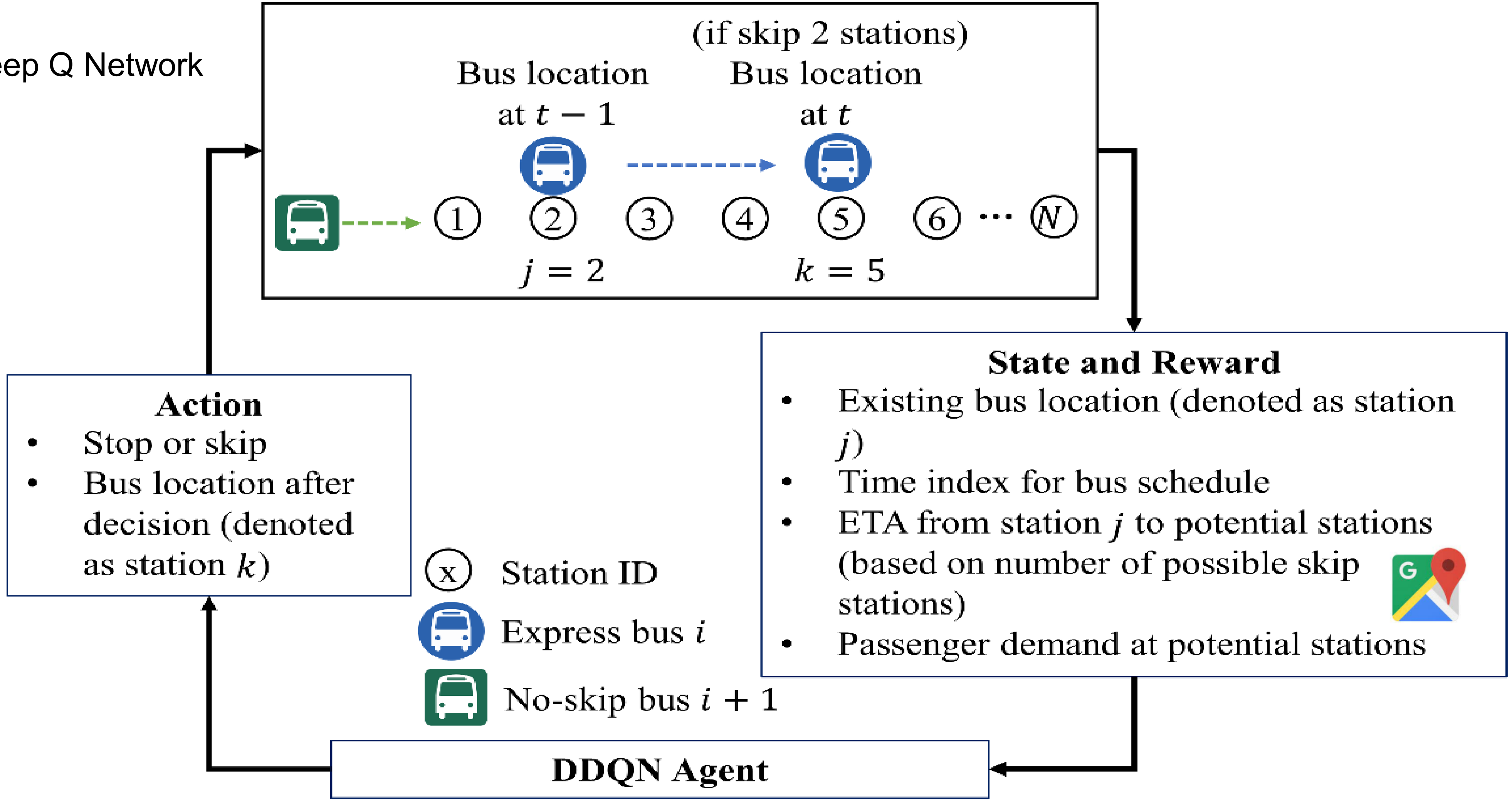
- The authors in [7] utilized a genetic algorithm (GA) aided by a Monte Carlo simulation. To reduce the risk of passenger service imbalance, they considered bus route optimization comprising of one express lane, followed by another no-skip flow.
- The study in [9] also resorted to a GA approach but considered the factor of imbalanced passenger demand.
- **Limitation**: Deriving an optimal stop-skipping strategy requires full real-time traffic conditions for all bus stations. It is impractical since the traffic conditions may change when the bus moves to intermediate stops.

Proposed Solution (Deep Reinforcement Learning)



System Model

DDQN = Double Deep Q Network



System Settings

Parameters	Values
Number of stations	10
Frequency of express (no-skip) trip per trip	30 minutes
Dispatch interval between express and no skip trip	15 minutes
Learning rate	0.0005
Activation function	ReLU
Number of input nodes	8
Number of hidden layers	3
Number of hidden nodes	832
Number of output nodes	3
Batch size	32
Discount rate	0.4
Experience memory size	5000
Epsilon Decay	0.999

- Passenger demand, $P_{i,k} = U_{i,k} + V_{i,k}$
- Average waiting time of boarding passengers, $\overline{T_{w,k}} = \frac{H_{i,k}}{2}$
- In-vehicle time, $T_{v,jk} = (\tau_{j,k} + t_{j,k}) \cdot \frac{l_{i,j}}{l_{max}}$
- Bus running time, $T_{r,jk} = (\tau_{j,k} + t_{j,k})$
- Number of stranded passengers, $L_{i,k\text{-}1}$
- Average waiting time of stranded passengers: $\overline{T_{ws,k-1}} = \frac{H_{i,k-1}}{2} + H_{i+1,k-1}$

ASEAN IVO

UTAR UNIVERSITI TUNKU ABDUL RAHMAN

Wholly owned by UTAR Education Foundation (Co. No. 578227-M) DU012(A)

ITC-CSCC 2023

Reward Function

- One episode equals one express bus lane and one no-skip flow.
- The step reward function in the express trip: $R_{t1} = \frac{C_1 P_{i,k}}{C_2 \overline{T_{w,j}} + C_3 T_{v,jk} + C_4 T_{r,jk}} - 0.3$
- The step reward function in the no-skip trip: $R_{t2} = C_5 \frac{L_{i,\ k-1}}{\overline{\overline{T_{ws,k-1}}}}$
- An additional reward constraint, R, has been included to incentivize or penalize the agent's decision to reach the terminal station:

$$R = \begin{cases} 5 & \text{, if bus } i \text{ reached station } N \\ -5 & \text{, if bus } i \text{ unable to reach station } N \end{cases}$$

Wholly owned by UTAR Education Foundation (Co. No. 578227-M) DU012(A)

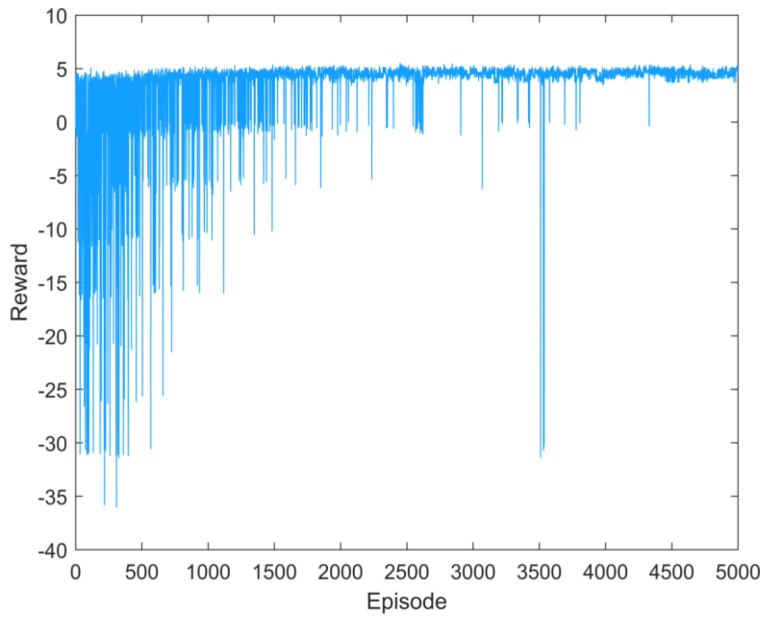
ITC-CSCC 2023

Bus Route and Estimated Time Arrival (ETA)

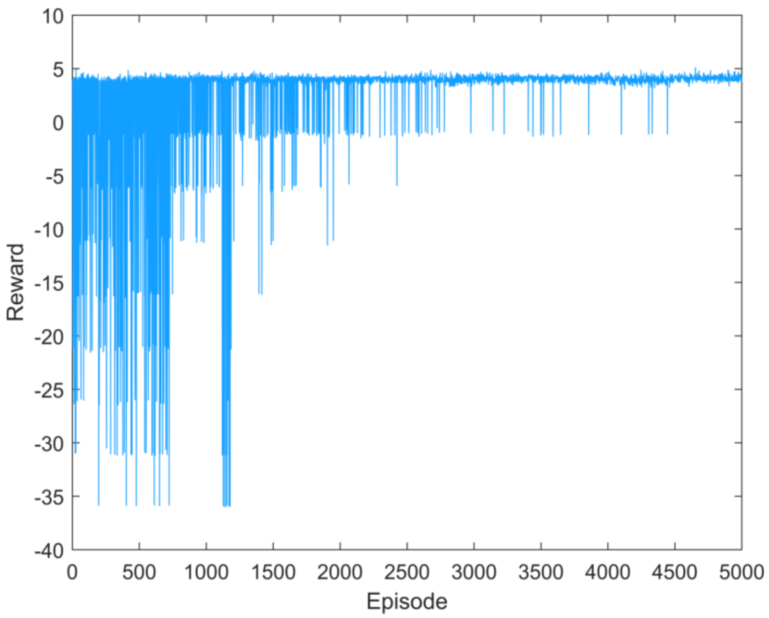
Origin	1			2			3			4			5			6			7			8		9
Destination	2	3	4	3	4	5	4	5	6	5	6	7	6	7	8	7	8	9	8	9	10	9	10	10
Departure Time																								
07:00:00	933	1168	1535	236	581	837	340	596	737	349	475	392	256	456	889	285	717	1070	479	832	826	350	329	231
07:30:00	851	1083	1423	225	575	827	364	604	736	371	494	399	246	465	894	287	714	1080	479	845	819	352	328	219
08:00:00	830	1062	1413	222	602	827	336	587	715	345	463	373	244	472	892	270	695	1051	478	834	808	324	298	231
08:30:00	850	1067	1414	227	569	836	332	611	767	367	519	388	254	474	910	274	708	1053	469	814	792	323	315	227
09:00:00	807	1001	1350	204	533	909	347	606	772	361	509	388	264	477	954	279	743	1102	493	852	832	348	356	247
09:30:00	786	977	1345	200	580	1112	360	791	987	497	693	506	286	533	1090	293	832	1219	585	972	960	330	336	237
10:00:00	825	1016	1416	195	555	1120	358	978	1226	713	961	846	322	654	1346	333	1018	1425	690	1088	1065	398	376	255
10:30:00	884	1080	1421	183	579	1054	391	943	1203	695	955	784	454	780	1493	444	1177	1559	732	1115	1067	374	342	250
11:00:00	852	1050	1372	208	535	848	320	694	871	461	665	554	352	641	1328	372	1059	1407	751	1096	1063	385	345	249
11:30:00	841	1041	1365	208	531	802	324	603	756	357	563	394	347	564	1137	310	890	1213	679	1002	964	366	353	251
12:00:00	779	981	1319	197	549	782	347	586	684	345	427	392	284	485	982	308	807	1129	592	914	914	340	321	228
12:30:00	767	952	1274	181	516	752	340	572	653	336	414	385	272	461	894	296	731	1064	525	857	828	360	336	229
13:00:00	728	898	1229	186	513	774	326	580	609	334	402	383	264	418	837	301	721	1018	478	774	759	330	301	225
13:30:00	721	893	1217	175	491	735	321	562	584	335	354	371	220	402	793	285	678	937	456	715	700	332	300	227
14:00:00	705	882	1196	176	493	728	318	552	573	327	333	364	203	385	777	277	669	935	438	705	696	284	245	216
14:30:00	693	860	1147	165	455	695	290	532	525	315	300	351	179	381	756	270	646	949	430	733	719	283	270	195
15:00:00	655	813	1102	161	445	684	284	519	503	302	274	345	150	361	728	259	627	894	412	674	673	271	245	179
15:30:00	698	857	1132	152	430	696	278	519	498	300	277	328	164	358	715	246	604	858	405	652	634	226	224	187
16:00:00	567	719	984	141	426	659	285	529	495	305	288	338	169	354	702	253	596	804	392	611	614	236	236	178
16:30:00	542	684	970	140	422	653	281	521	494	288	266	324	151	346	690	244	589	795	381	604	594	223	226	210
17:00:00	497	627	911	146	451	642	304	511	490	305	297	333	156	339	662	227	553	741	361	554	542	204	204	181
17:30:00	486	623	883	150	427	639	276	496	483	270	259	308	143	339	660	217	533	726	330	533	524	204	219	181
18:00:00	506	645	915	152	425	633	272	494	469	278	264	316	141	335	646	222	539	745	348	530	530	175	182	169
18:30:00	485	618	904	152	434	637	281	484	455	250	236	311	117	337	646	220	534	753	338	499	504	160	166	155

DDQN Training Results

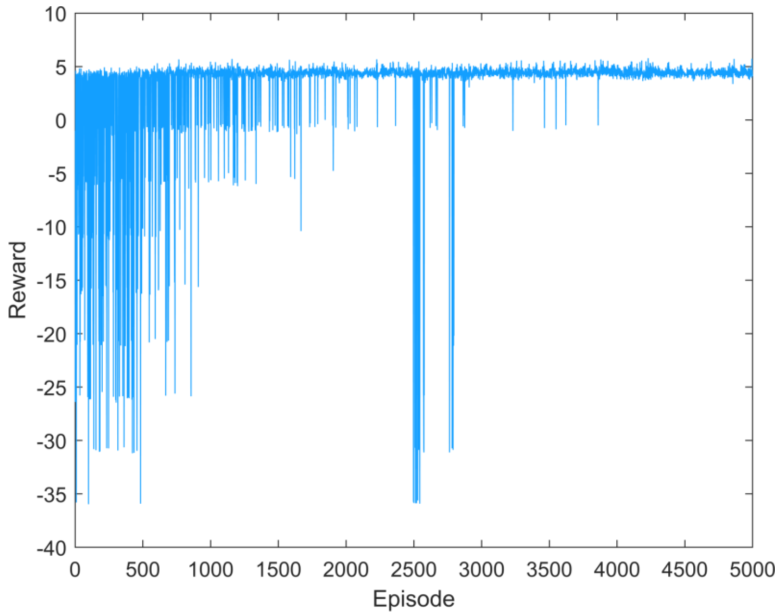
- Three passenger demand scenarios are considered:
  - **Scenario 1**: Static passenger demand
  - **Scenario 2**: Dynamic passenger demand varied with time
  - **Scenario 3**: Random passenger demand.



Scenario 1



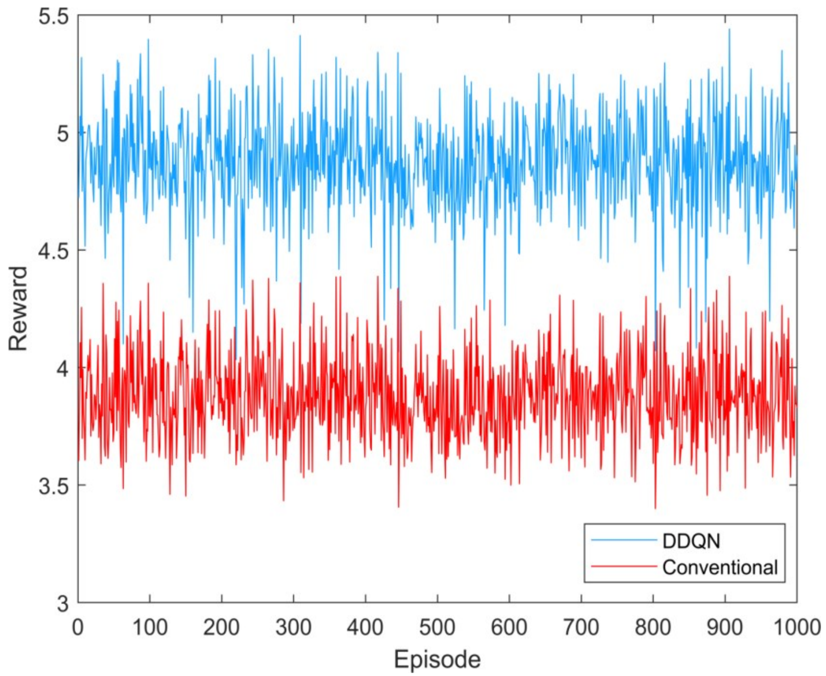
Scenario 2



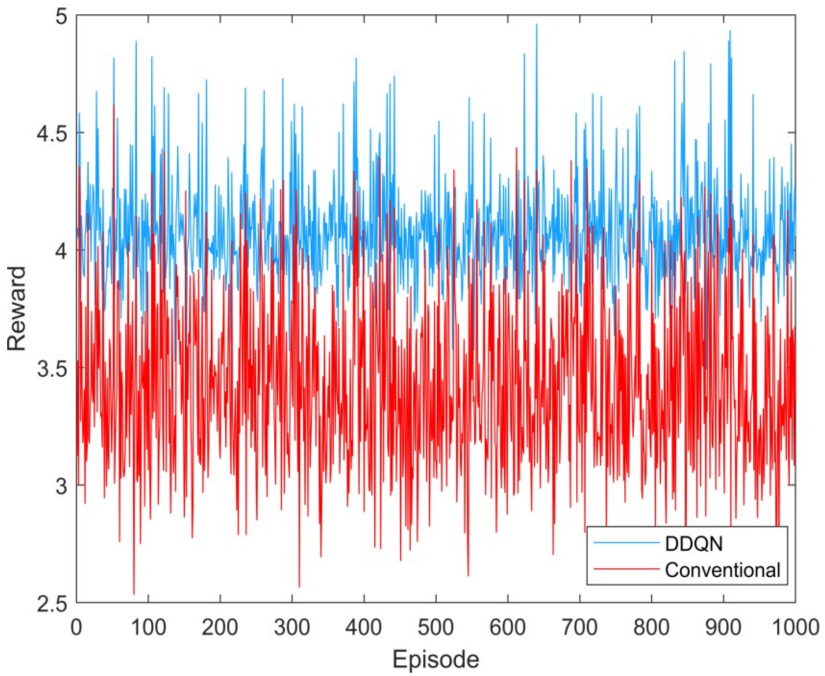
Scenario 3

DDQN Evaluation Results

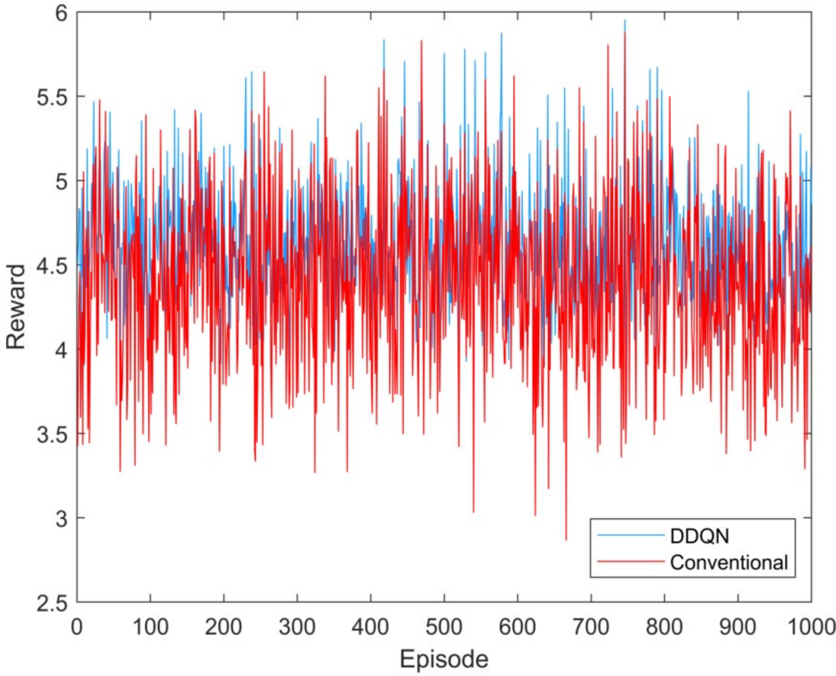
- **Conventional method** adopts two no-skip routes.



Scenario 1



Scenario 2



Scenario 3

DDQN Stop-Skipping Patterns

Scenario 1

Station	0	1	2	3	4	5	6	7	8	9
Boarding Demand	12	8	0	0	0	3	0	0	0	0
Skip (0)/Stop (1)	1	1	0	1	0	1	1	0	0	1
Alighting Demand	0	3	0	2	0	4	4	0	0	10

Scenario 2

Station	0	1	2	3	4	5	6	7	8	9
Boarding Demand	10	0	4	4	1	3	2	0	1	0
Skip (0)/Stop (1)	1	0	1	1	0	1	1	0	0	1
Alighting Demand	0	2	0	3	0	5	4	0	0	9

Scenario 3

Station	0	1	2	3	4	5	6	7	8	9
Boarding Demand	11	10	3	5	4	2	1	1	2	0
Skip (0)/Stop (1)	1	1	0	1	0	1	1	0	0	1
Alighting Demand	0	1	0	4	0	6	5	0	0	13

Conclusions

- A DDQN strategy for optimizing express bus routes based on passenger demand and ETA has been proposed.
- The reward function has been designed to reflect the satisfaction levels of both bus user and operator.
- The proposed scheme outperforms the traditional approach in all three different passenger demand scenarios.


Q&A