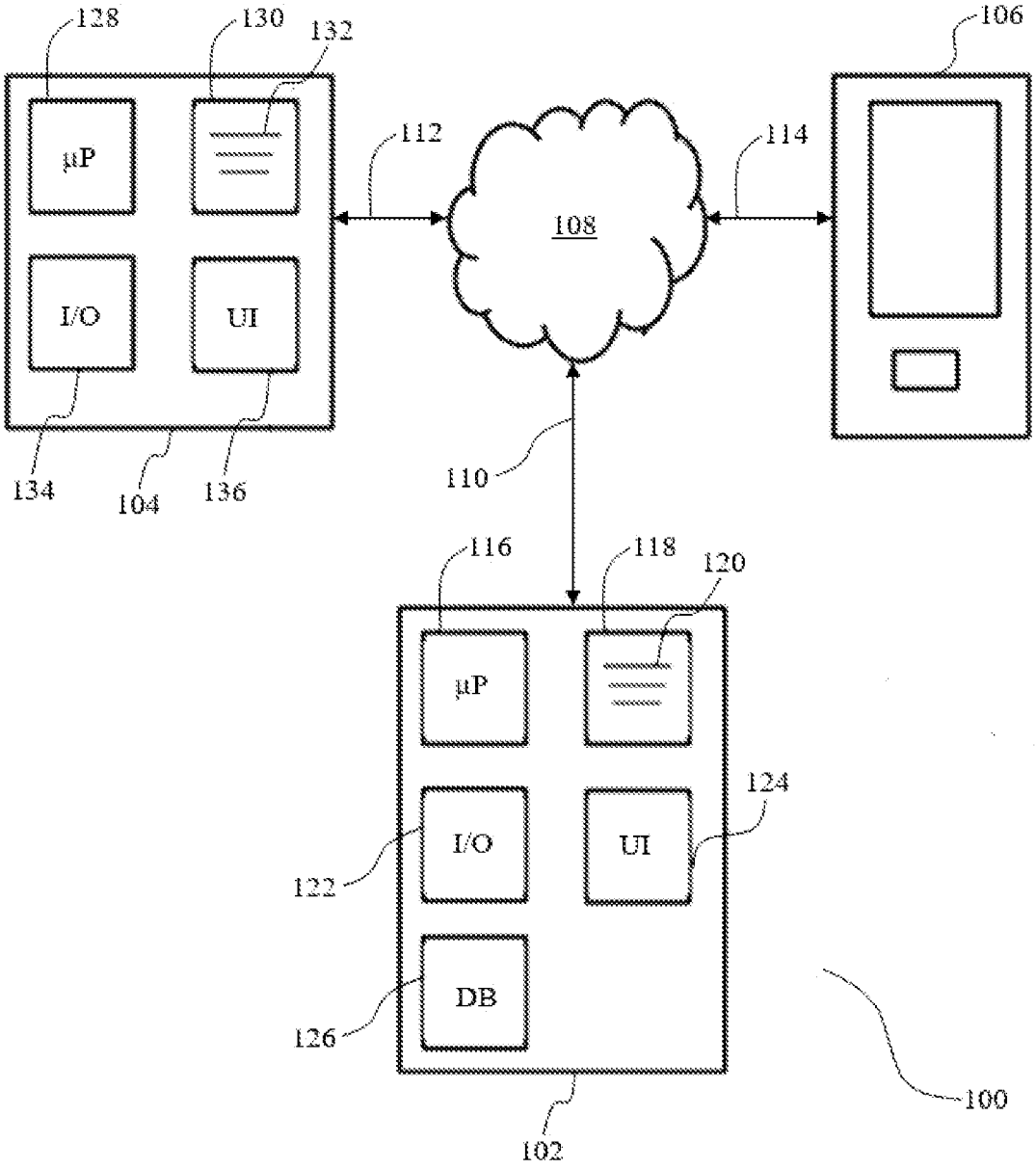

128
130
132
106
µP
112
114
108
I/O
UI
134
104
136
110
116
118
120
µP
124
I/O
UI
122
DB
126
100
102

FIG. 1

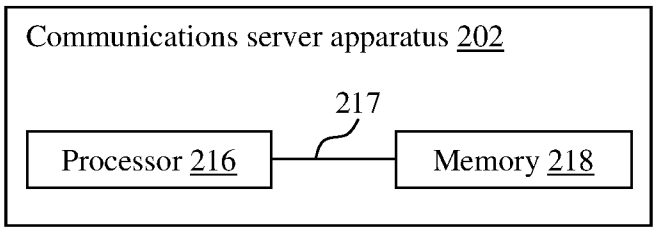

Communications server apparatus 202
217
Processor 216
Memory 218

FIG. 2A

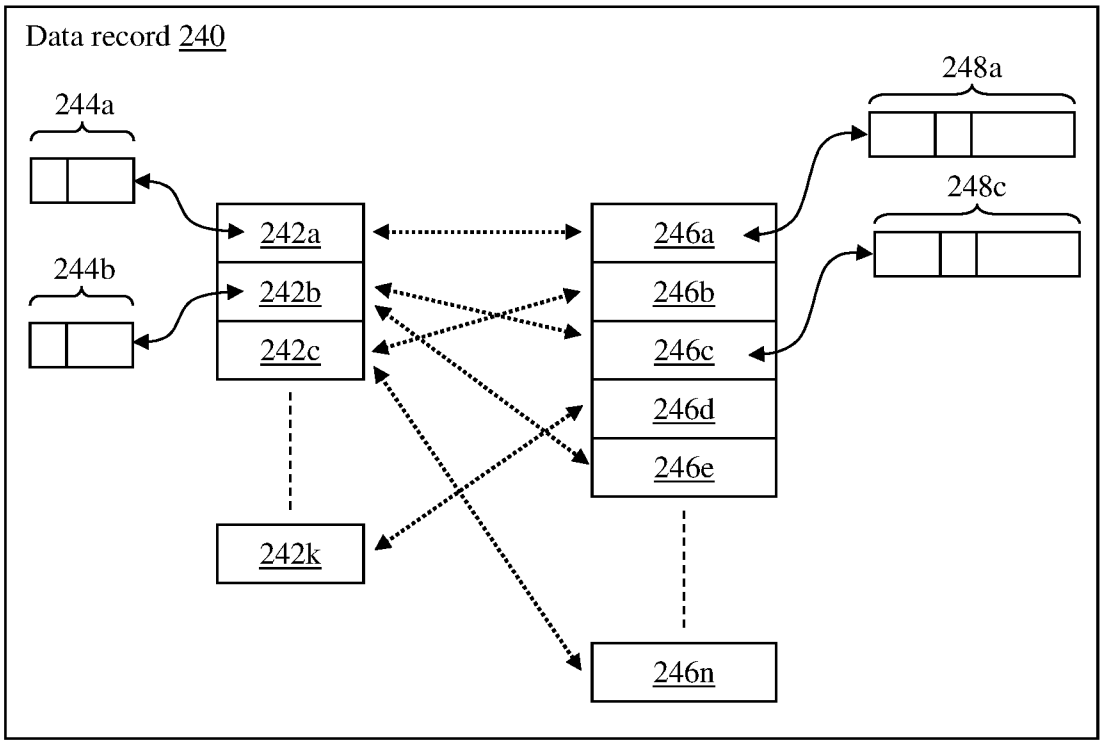

Data record 240
244a
244b
242a
242b
242c
242k
246a
246b
246c
246d
246e
246n
248a
248c

FIG. 2B

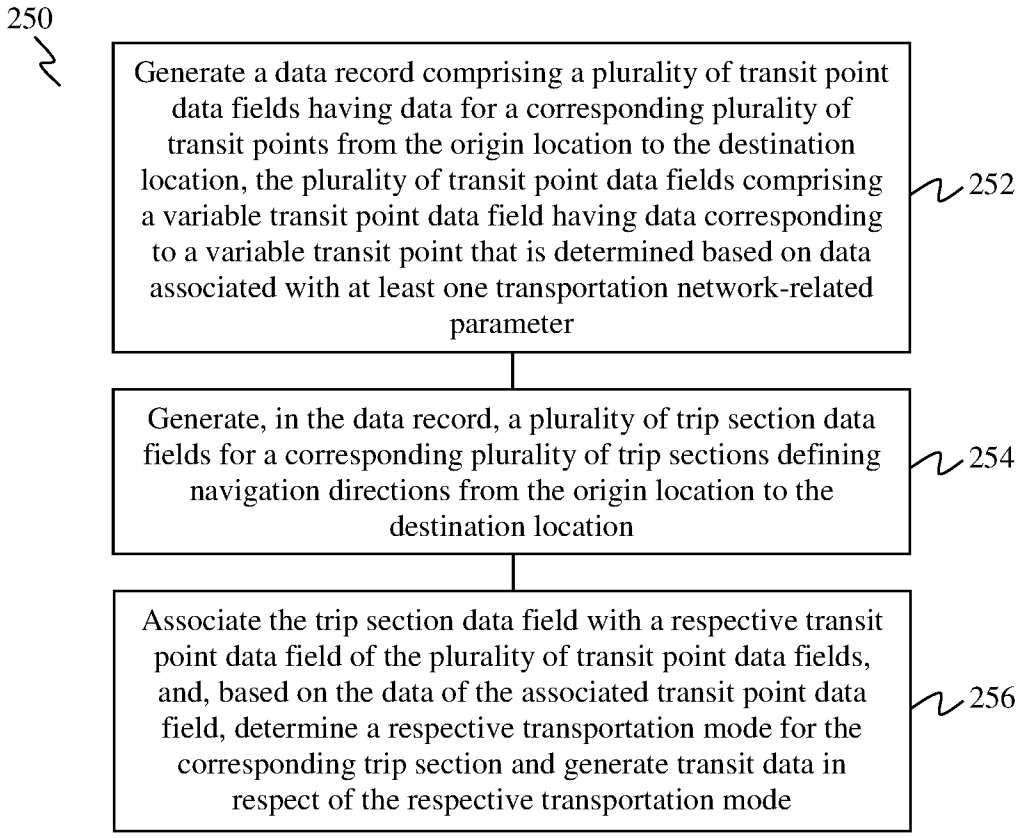

250
Generate a data record comprising a plurality of transit point data fields having data for a corresponding plurality of transit points from the origin location to the destination location, the plurality of transit point data fields comprising a variable transit point data field having data corresponding to a variable transit point that is determined based on data associated with at least one transportation network-related parameter
252
Generate, in the data record, a plurality of trip section data fields for a corresponding plurality of trip sections defining navigation directions from the origin location to the destination location
254
Associate the trip section data field with a respective transit point data field of the plurality of transit point data fields, and, based on the data of the associated transit point data field, determine a respective transportation mode for the corresponding trip section and generate transit data in respect of the respective transportation mode
256

FIG. 2C

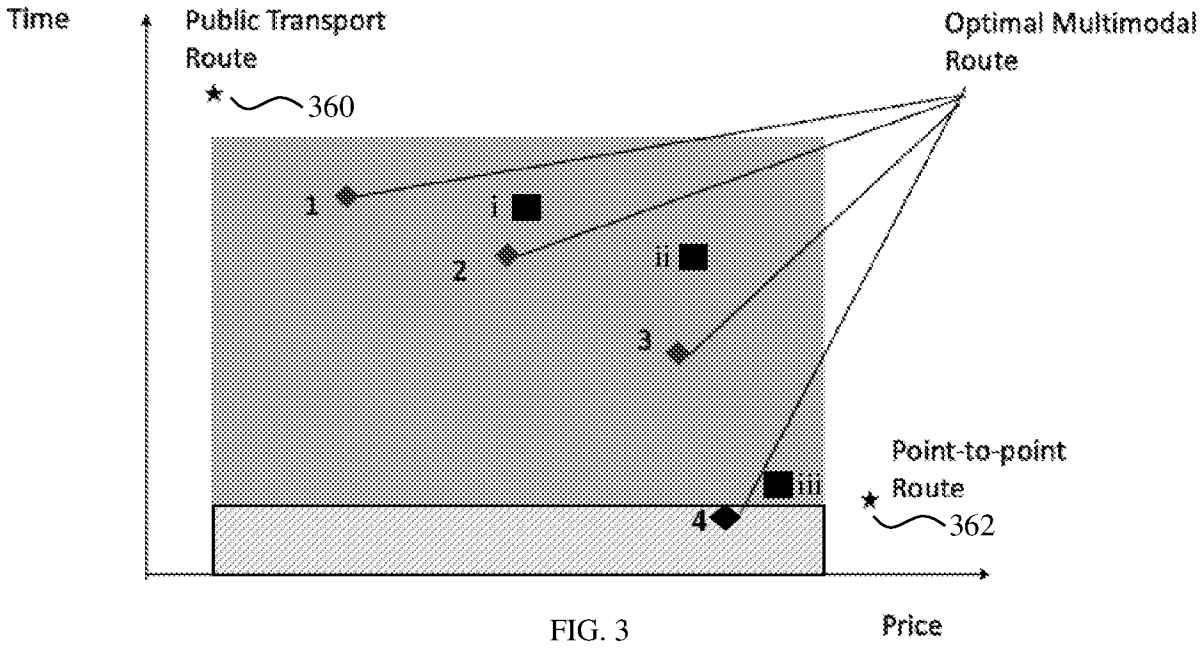

Time
Public Transport Route
360
Optimal Multimodal Route
1
i
2
ii
3
iii
4
Point-to-point Route
362
Price

FIG. 3

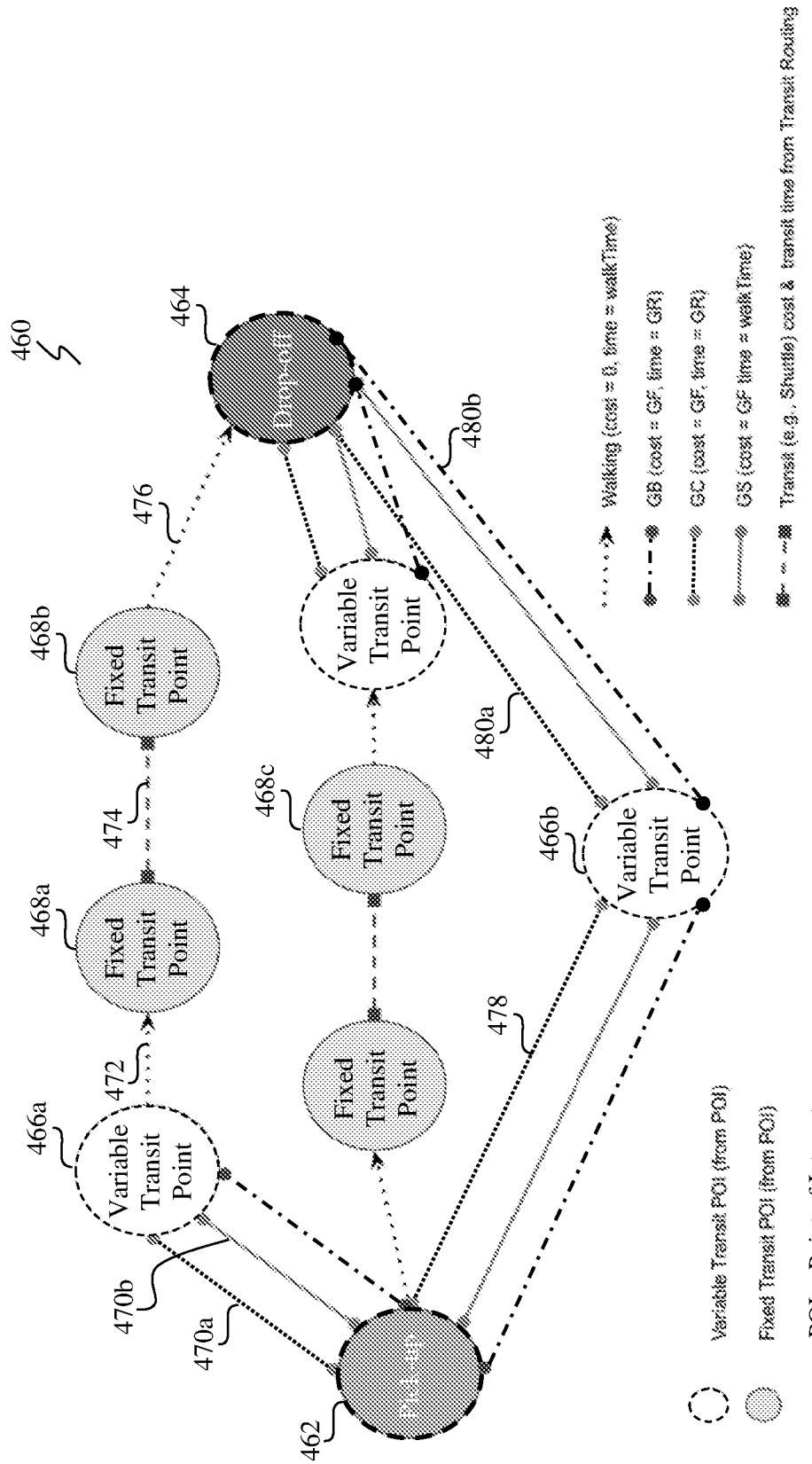

460
462
464
466a
466b
468a
468b
468c
470a
470b
472
474
476
478
480a
480b
Point-of-Interest
Point-of-Interest
Variable Transit Point
Variable Transit Point
Variable Transit Point
Fixed Transit Point
Fixed Transit Point
Fixed Transit Point
Fixed Transit Point
Walking (cost = 0, time = walkTime)
GB (cost = GF, time = GR)
GC (cost = GF, time = GR)
GS (cost = GF time = walk time)
Transit (e.g., Shuttle) cost & transit time from Transit Routing
Variable Transit POI (from POI)
Fixed Transit POI (from POI)
POI = Point of Interest

FIG. 4

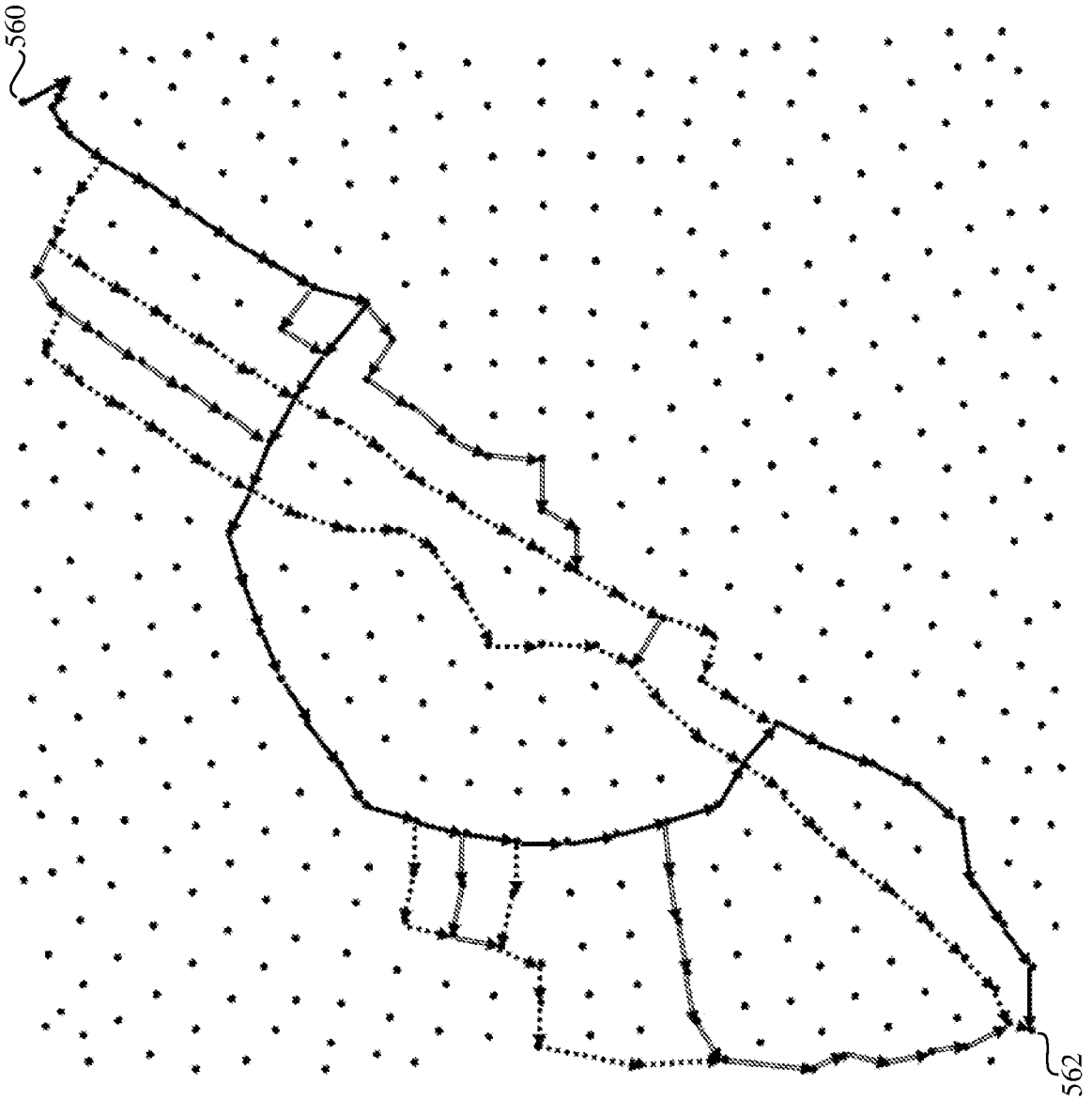


FIG. 5A

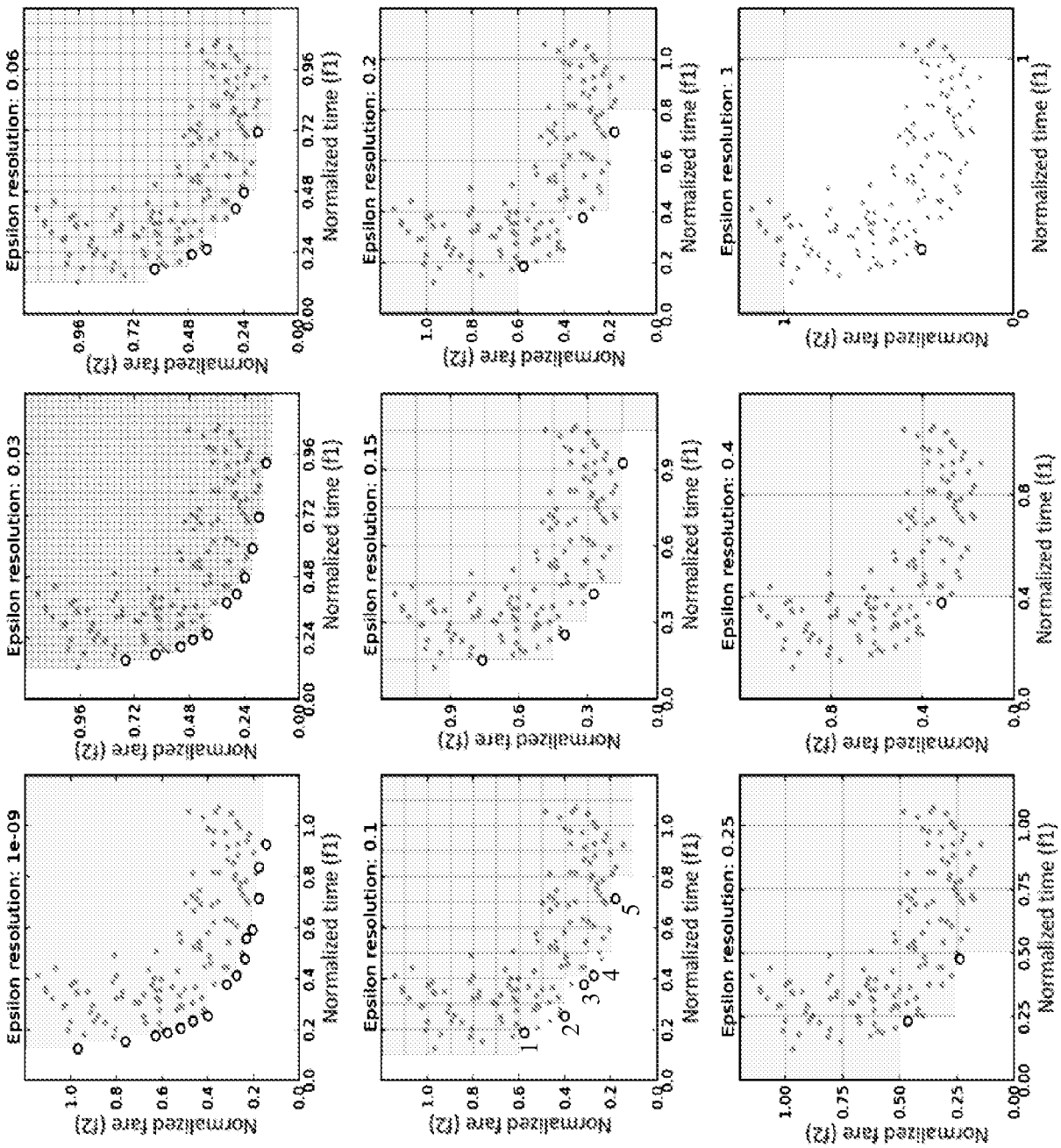

Epsilon resolution: 1e-09
Epsilon resolution: 0.03
Epsilon resolution: 0.06
Epsilon resolution: 0.1
Epsilon resolution: 0.15
Epsilon resolution: 0.2
Epsilon resolution: 0.25
Epsilon resolution: 0.4
Epsilon resolution: 1
Normalized fare (f2)
Normalized time (f1)
1
2
3
4
5

FIG. 5B

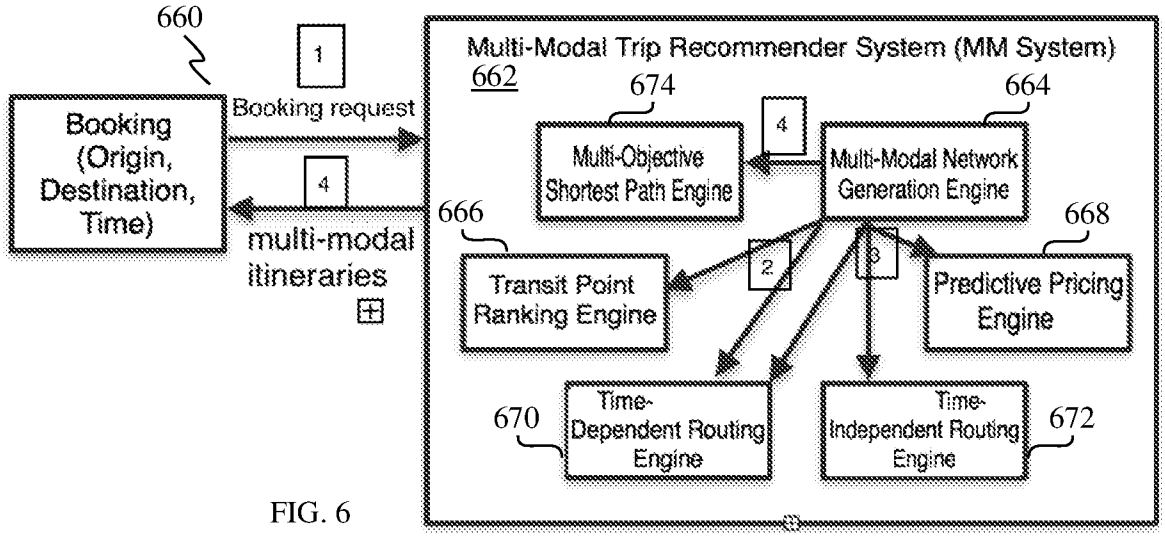

660
Booking (Origin, Destination, Time)
1
Booking request
4
multi-modal itineraries
Multi-Modal Trip Recommender System (MM System)
662
674
Multi-Objective Shortest Path Engine
4
664
Multi-Modal Network Generation Engine
666
Transit Point Ranking Engine
2
3
668
Predictive Pricing Engine
670
Time-Dependent Routing Engine
Time-Independent Routing Engine
672

FIG. 6

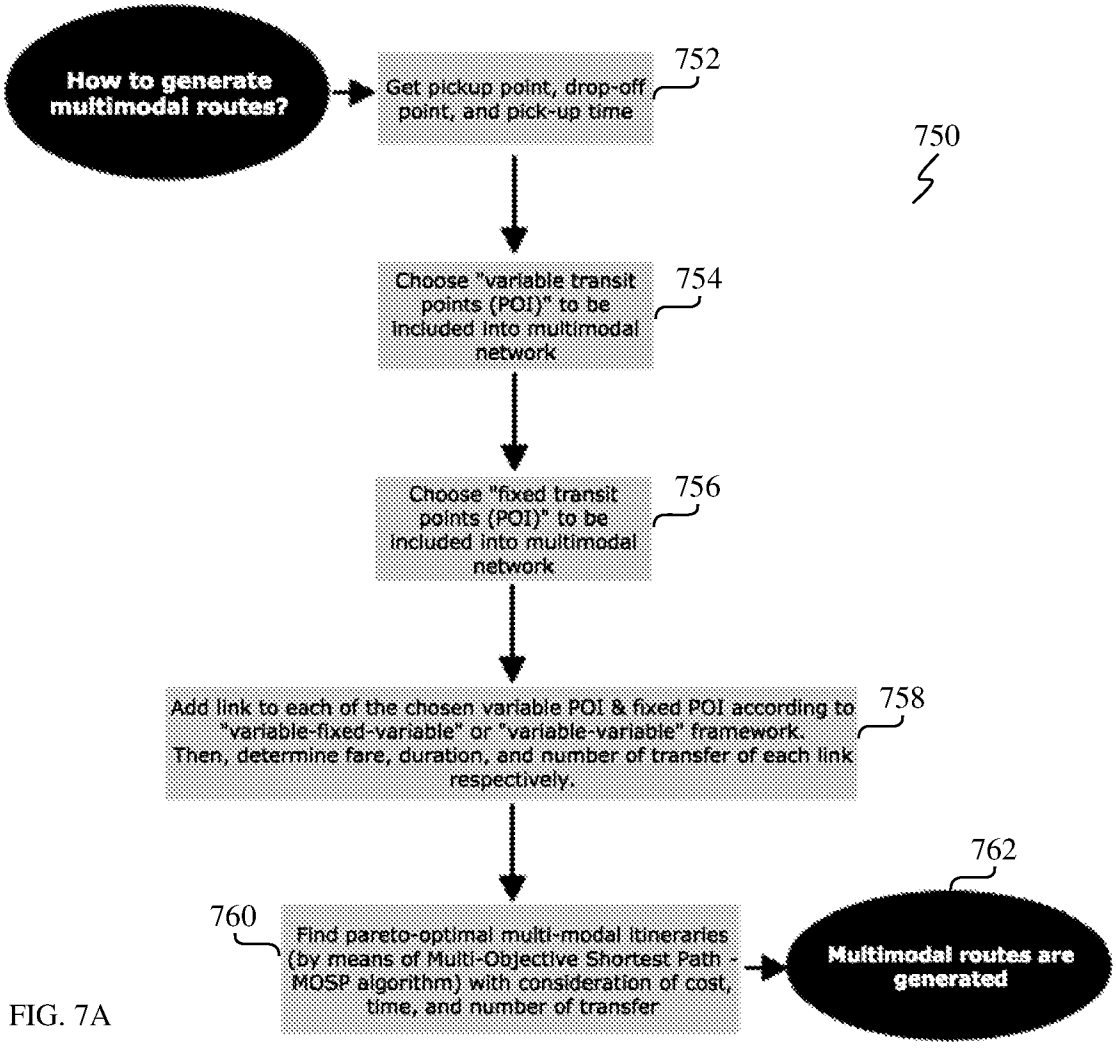

How to generate multimodal routes?
Get pickup point, drop-off point, and pick-up time
752
750
Choose "variable transit points (POI)" to be included into multimodal network
754
Choose "fixed transit points (POI)" to be included into multimodal network
756
Add link to each of the chosen variable POI & fixed POI according to "variable-fixed-variable" or "variable-variable" framework. Then, determine fare, duration, and number of transfer of each link respectively.
758
762
760
Find pareto-optimal multi-modal itineraries (by means of Multi-Objective Shortest Path - MOSP algorithm) with consideration of cost, time, and number of transfer
Multimodal routes are generated

FIG. 7A

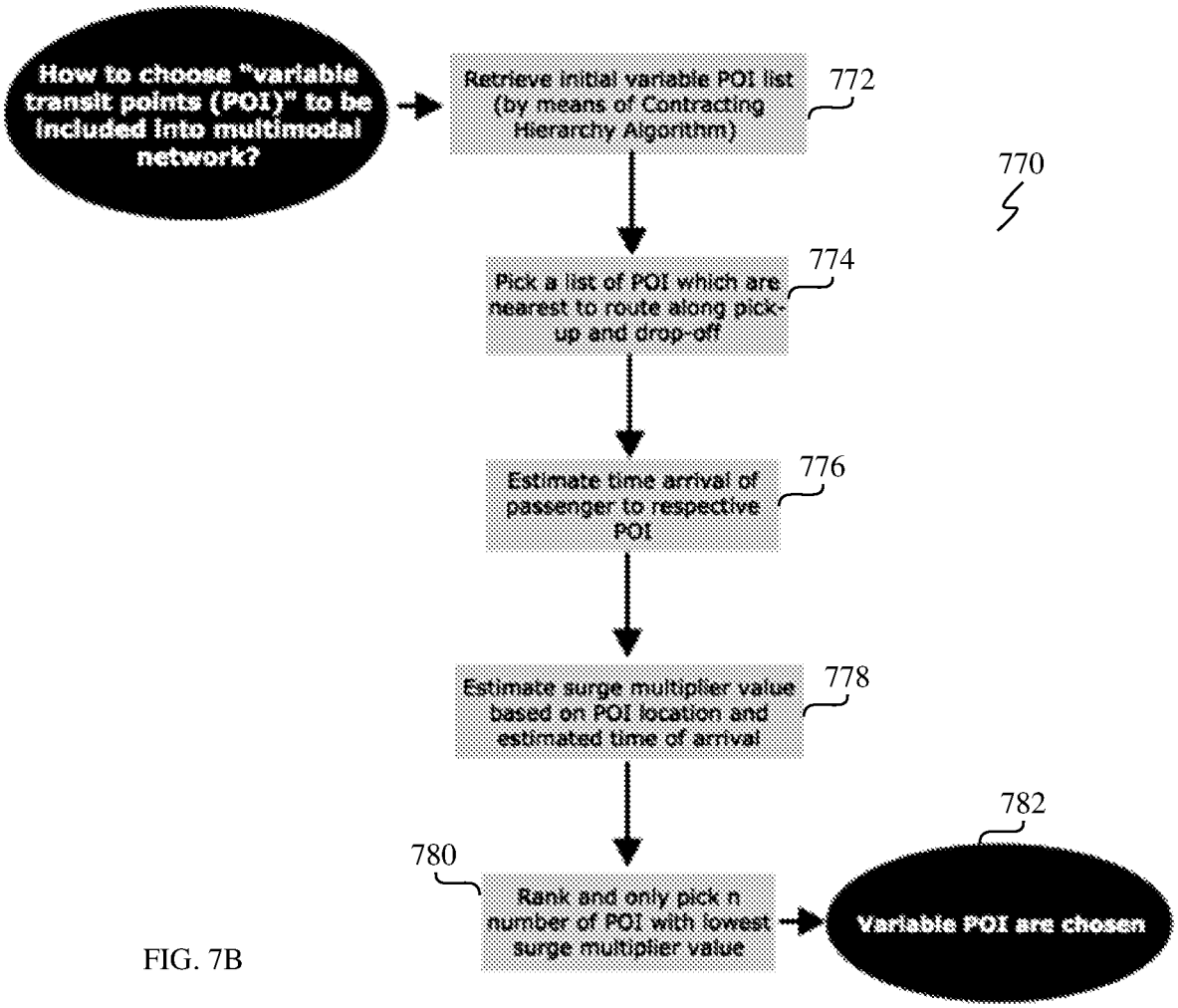

How to choose "variable transit points (POI)" to be included into multimodal network?
Retrieve initial variable POI list (by means of Contracting Hierarchy Algorithm)
772
770
Pick a list of POI which are nearest to route along pick-up and drop-off
774
Estimate time arrival of passenger to respective POI
776
Estimate surge multiplier value based on POI location and estimated time of arrival
778
780
Rank and only pick n number of POI with lowest surge multiplier value
782
Variable POI are chosen

FIG. 7B

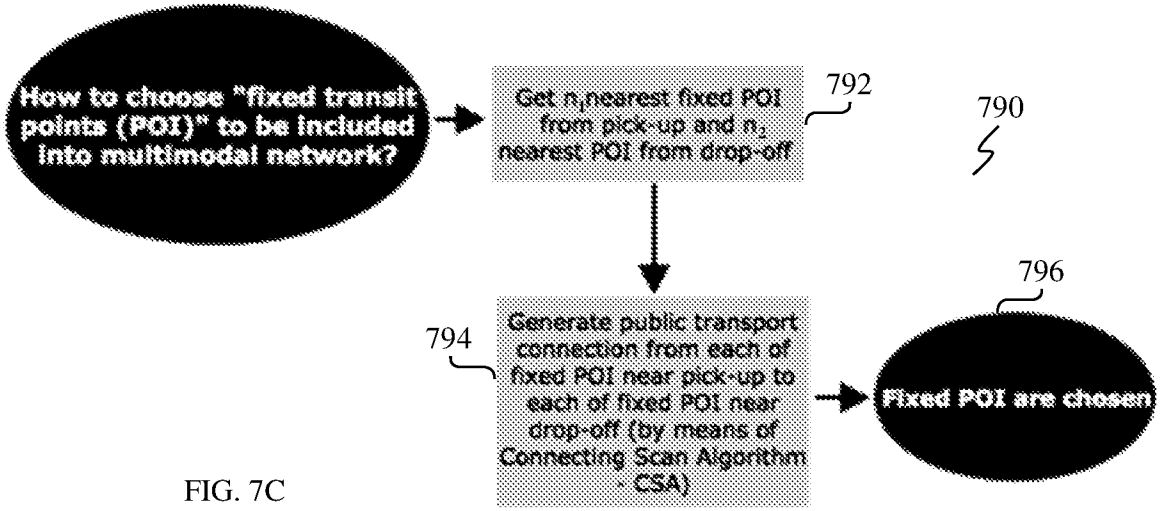

How to choose "fixed transit points (POI)" to be included into multimodal network?
Get n_1 nearest fixed POI from pick-up and n_2 nearest POI from drop-off
792
790
794
Generate public transport connection from each of fixed POI near pick-up to each of fixed POI near drop-off (by means of Connecting Scan Algorithm - CSA)
796
Fixed POI are chosen

FIG. 7C

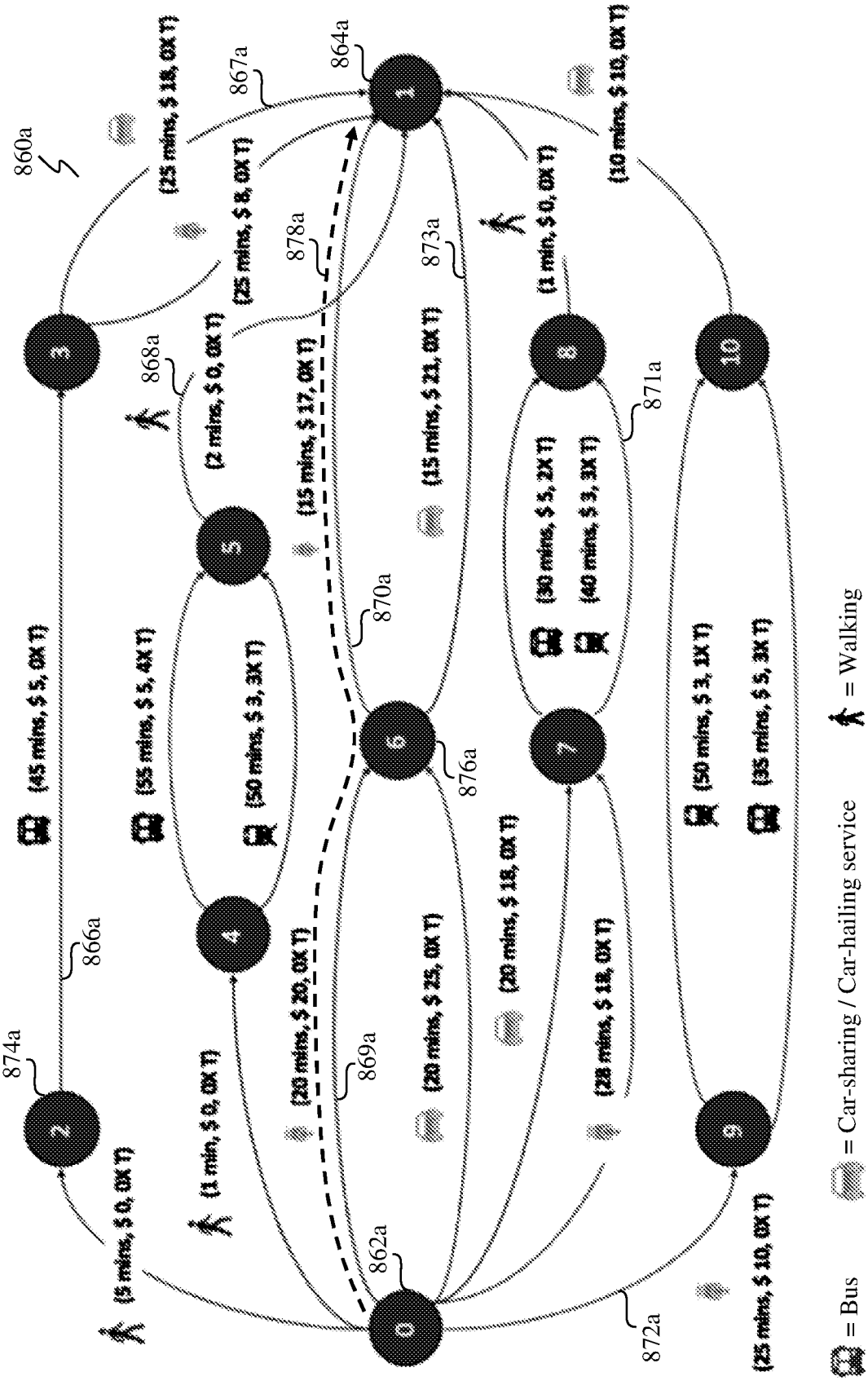

860a
862a
864a
866a
867a
868a
869a
870a
871a
872a
873a
874a
876a
878a
(5 mins, $ 0, 0X T)
(45 mins, $ 5, 0X T)
(25 mins, $ 18, 0X T)
(1 min, $ 0, 0X T)
(55 mins, $ 5, 4X T)
(2 mins, $ 0, 0X T)
(25 mins, $ 8, 0X T)
(20 mins, $ 20, 0X T)
(50 mins, $ 3, 3X T)
(15 mins, $ 17, 0X T)
(20 mins, $ 25, 0X T)
(15 mins, $ 21, 0X T)
(20 mins, $ 18, 0X T)
(1 min, $ 0, 0X T)
(30 mins, $ 5, 2X T)
(40 mins, $ 3, 3X T)
(28 mins, $ 18, 0X T)
(10 mins, $ 10, 0X T)
(50 mins, $ 3, 1X T)
(35 mins, $ 5, 3X T)
(25 mins, $ 10, 0X T)
= Bus
= Car-sharing / Car-hailing service
= Walking
= Rail
= Bike-hailing service

FIG. 8A

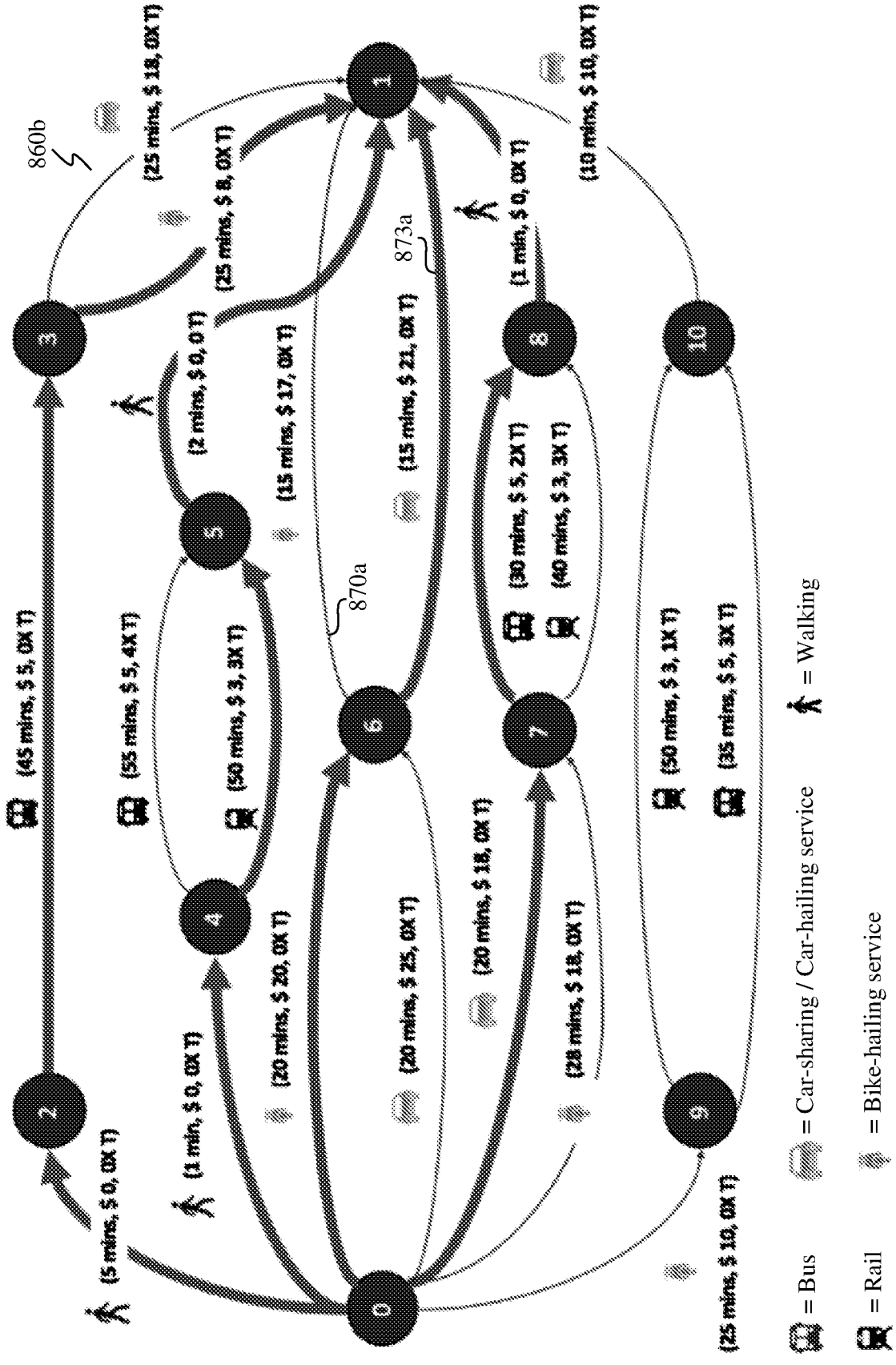

860b
870a
873a
(5 mins, $ 0, 0X T)
(1 min, $ 0, 0X T)
(45 mins, $ 5, 0X T)
(53 mins, $ 5, 4X T)
(50 mins, $ 3, 3X T)
(20 mins, $ 20, 0X T)
(2 mins, $ 0, 0 T)
(15 mins, $ 17, 0X T)
(25 mins, $ 8, 0X T)
(25 mins, $ 18, 0X T)
(20 mins, $ 25, 0X T)
(15 mins, $ 21, 0X T)
(1 min, $ 0, 0X T)
(10 mins, $ 10, 0X T)
(30 mins, $ 5, 2X T)
(40 mins, $ 3, 3X T)
(20 mins, $ 18, 0X T)
(28 mins, $ 18, 0X T)
(50 mins, $ 3, 1X T)
(35 mins, $ 5, 3X T)
(25 mins, $ 10, 0X T)
= Bus
= Car-sharing / Car-hailing service
= Walking
= Rail
= Bike-hailing service

FIG. 8B

Name	Type	Purpose
Road Network	Directed Graph	graph where nodes are streets (or intersections) and edges are intersections (or streets) connecting the nodes.
Transit Network	Directed Graph	graph where nodes are designated stops and edges are connections.
Multi-Modal Network	Directed Multi-Edge Graph	graph to encode possible multi-modal itineraries from O to D
Real-Time Connections	Data Stream	a stream of connections between designated transit stops sorted by their departure times.
Historical Trips	Database	For metric forecasting and transit points ranking.
Itinerary Comparator	Priority Queue	To sort multi-modal itineraries with respect to a specific criterion.
Non-Dominated Archive	Pareto Approximation Set	To maintain the set of optimal multi-modal itineraries based on the Multi-Modal Network

FIG. 9

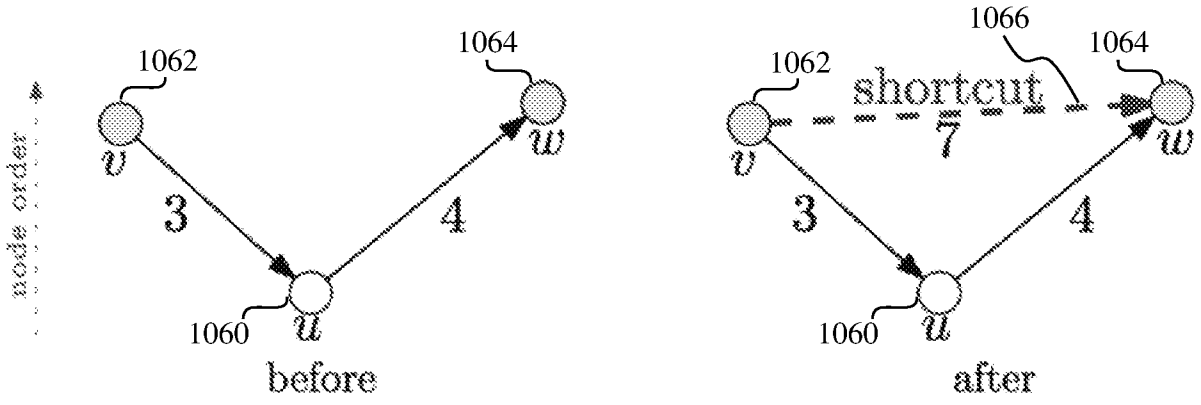


FIG. 10A

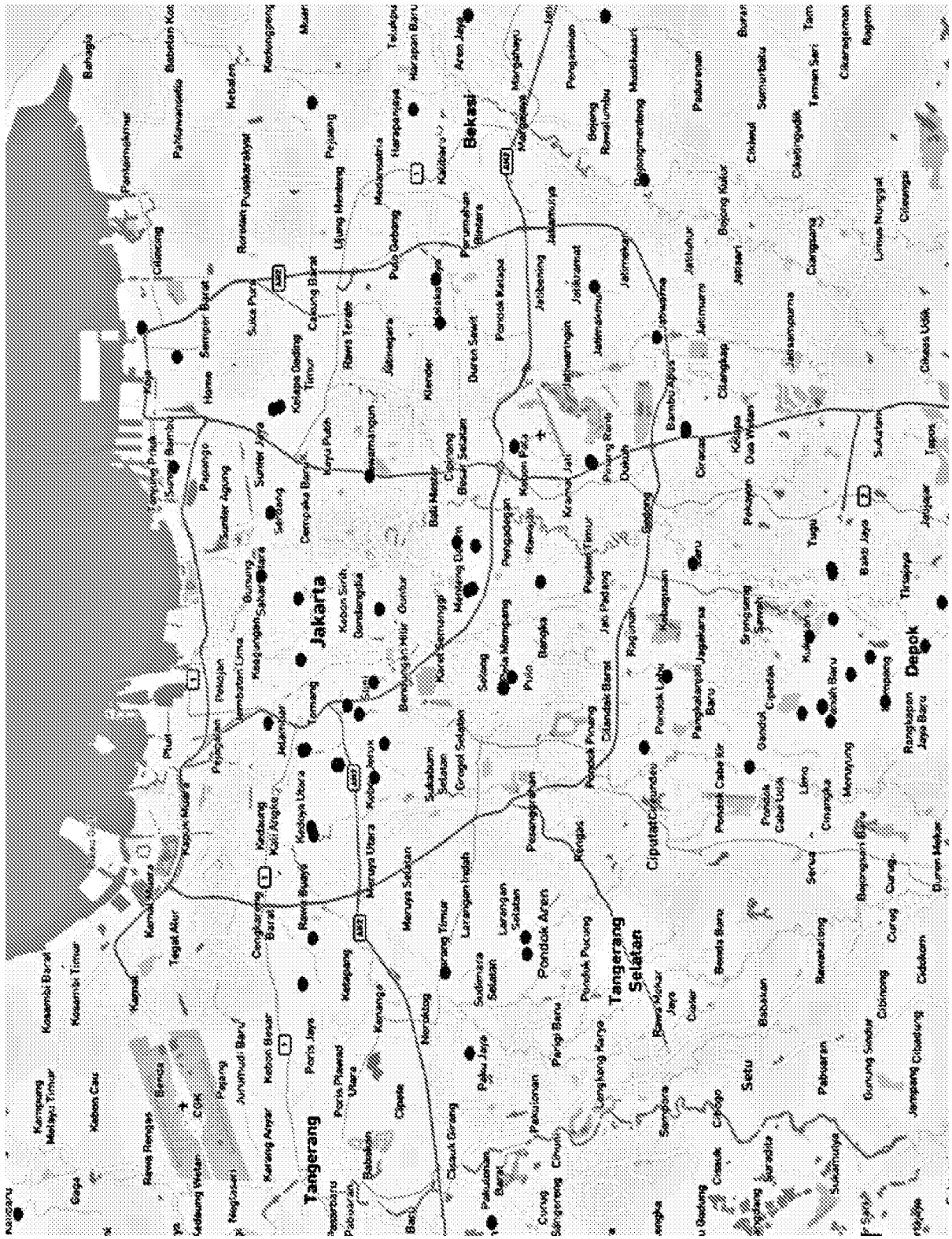


FIG. 10B