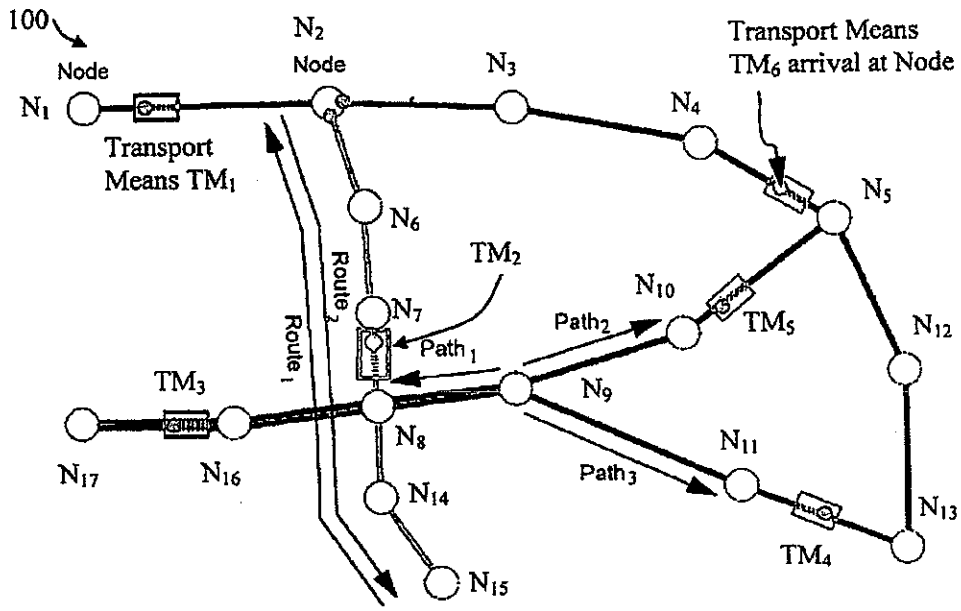

100
Node
N1
N2
Node
N3
N4
Transport Means
TM6 arrival at Node
Transport
Means TM1
N5
N6
TM2
Route2
N7
Route1
Path2
N10
TM5
N12
Path1
TM3
N9
N8
N11
N17
N16
N14
Path3
N13
TM4
N15

Figure 1

Node N_1 Departure Opportunities		
Reference Time: 0900 hours		
N_1	Nodes	Latest possible departure time from respective Nodes
	1	N_1, -
	2	N_2, 0855
	3	N_3, 0850
	4	N_4, 0845
	5	N_5, 0840
	6	N_6, 0851
	7	N_7, 0846
	8	N_8, 0841
	9	N_9, 0834
	10	N_{10},0830
	11	N_{11}, 0829
	12	N_{12}, 0837
	13	N_{13}, 0825
	14	N_{14}, 0835
	15	N_{15}, 0828
	16	N_{16}, 0836
	17	N_{17}, 0829

Figure 2A

Node N_2 Departure Opportunities		
Reference Time: 0900 hours		
N_2	Nodes	Latest possible departure time from respective Nodes
	1	N_1, 0855
	2	N_2, -
	3	N_3, 0855
	4	N_4, 0850
	5	N_5, 0844
	6	N_6, 0854
	7	N_7, 0844
	8	N_8, 0843
	9	N_9, 0837
	10	N_{10}, 0833
	11	N_{11}, 0832
	12	N_{12}, 0839
	13	N_{13}, 0833
	14	N_{14}, 0839
	15	N_{15}, 0833
	16	N_{16}, 0830
	17	N_{17}, 0825

Figure 2B

Transport Means TM_1 Departures/Arrivals

TM_1		Arrival Time	Departure Time
	N_1	0900	
	N_2	0854	0855 *
	N_3	0849	0850 *
	N_4	0844	0845 *
	N_5	0839	0840 *
	N_{12}	0836	0837 *
	N_{13}	0800	0826
	N_{12}	0754	0755
	N_5	0749	0750
	N_4	0744	0745
	N_3	0739	0740
	N_2	0734	0735
First Run	N_1	-	0730

By way of example these are the latest possible departure times from these Nodes and coincide with NODE N_1 Departure Opportunities (*)

Note that this time is not the latest

This TM does not take any other route so it does not visit any other Nodes. Its route is between N_1 and N_{13} via $N_2 N_3 N_4 N_5 N_{12}$ - N_{13}

Figure 3

Transport Means TM_2 Departures/Arrivals

TM_2		Arrival Time	Departure Time
	N_1	0859	-
	N_2	0853	0854
	N_6	0850	0851 *
	N_7	0845	0846 *
	N_8	0840	0841 *
	N_{14}	0834	0835 *
First Run	N_{15}	-	0828 *

TM_1 was earlier so its departure time is recorded at N_1 for N_2 latest possible departure time

* refer Node N_1 Departure Opportunities

Figure 4

Transport Means TM_3 Departures/Arrivals

TM_3		Arrival Time	Departure Time
	N_1	0858	-
	N_2	-	0851
	N_6	-	0849
	N_7	0845	0844 *
	N_8	0838	0839
	N_{16}	0835	0836 *
First Run	N_{17}	-	0829 *

Runs express so as to provide the latest possible departure time at N_1 from N_7

Node N_1 Departure Opportunities

Figure 5

Transport Means TM_4 Departures/Arrivals

TM_4		Arrival Time	Departure Time	
	N_{17}	0859	-	
	N_{16}	0854	0855	
	N_8	0839	0840	
	N_9	0832	0833	
	N_{11}	0828	0829 *	
First Run	N_{13}	-	0825 *	

Runs expressed so as to provide the latest possible departure time at N_1 from N_7 table N_1

Node N_1 Departure Opportunities

Figure 6

Object Entry/Exit

Object	Node & Time of Entry	Node & Time of Exit if it exists
1	N_{13}, 0820	-
2	N_{13}, 0821	N_5, 0941
3	N_{13}, 0810	N_2, 0956
4	N_{13}, 0810	-
5	N_{15}, 0820	N_1, 0900
6	N_{17}, 0828	-
7	N_{17}, 0820	N_7, 0848
O_N	N_{14}, 8:30	-

Figure 7

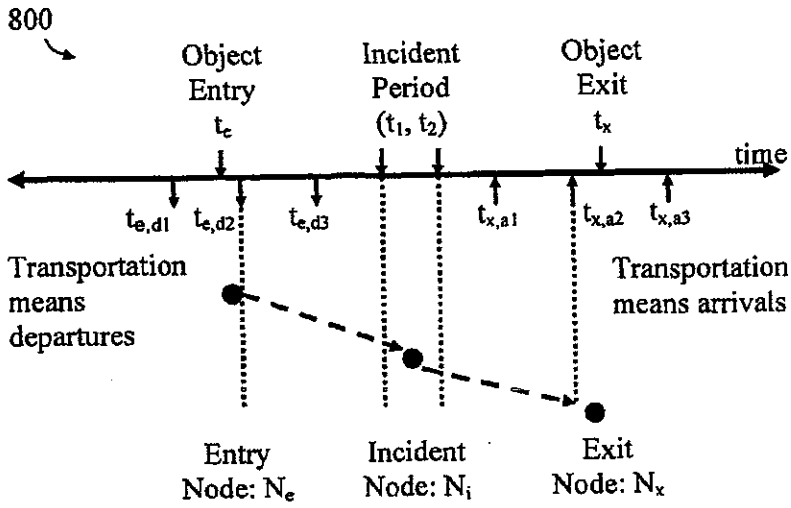


Figure 8

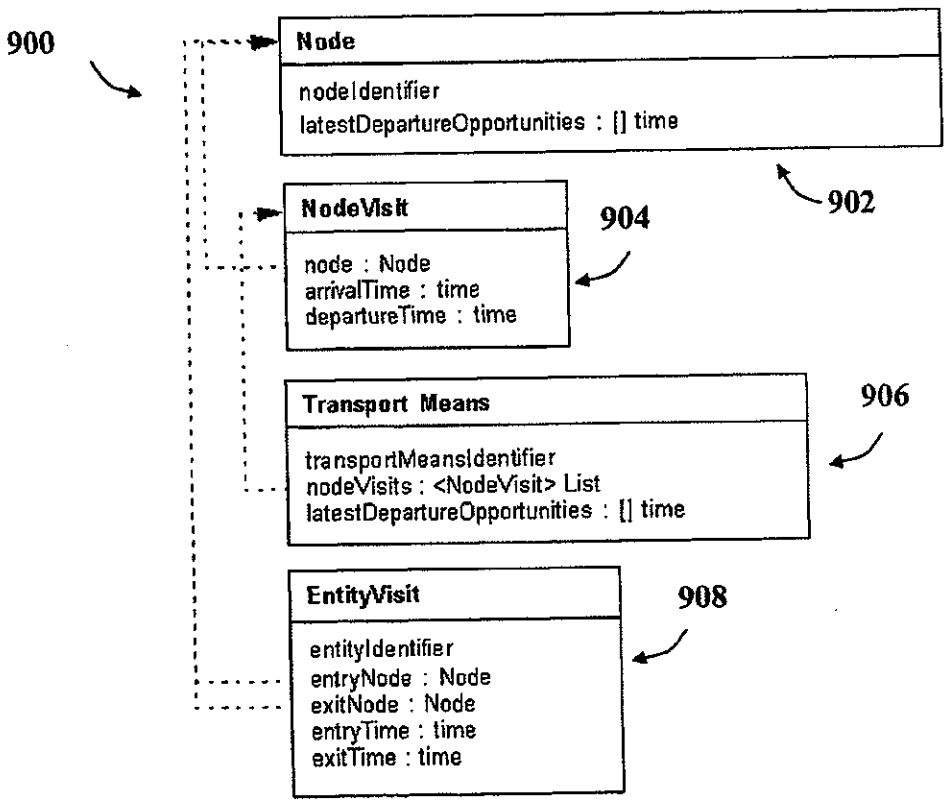


Figure 9

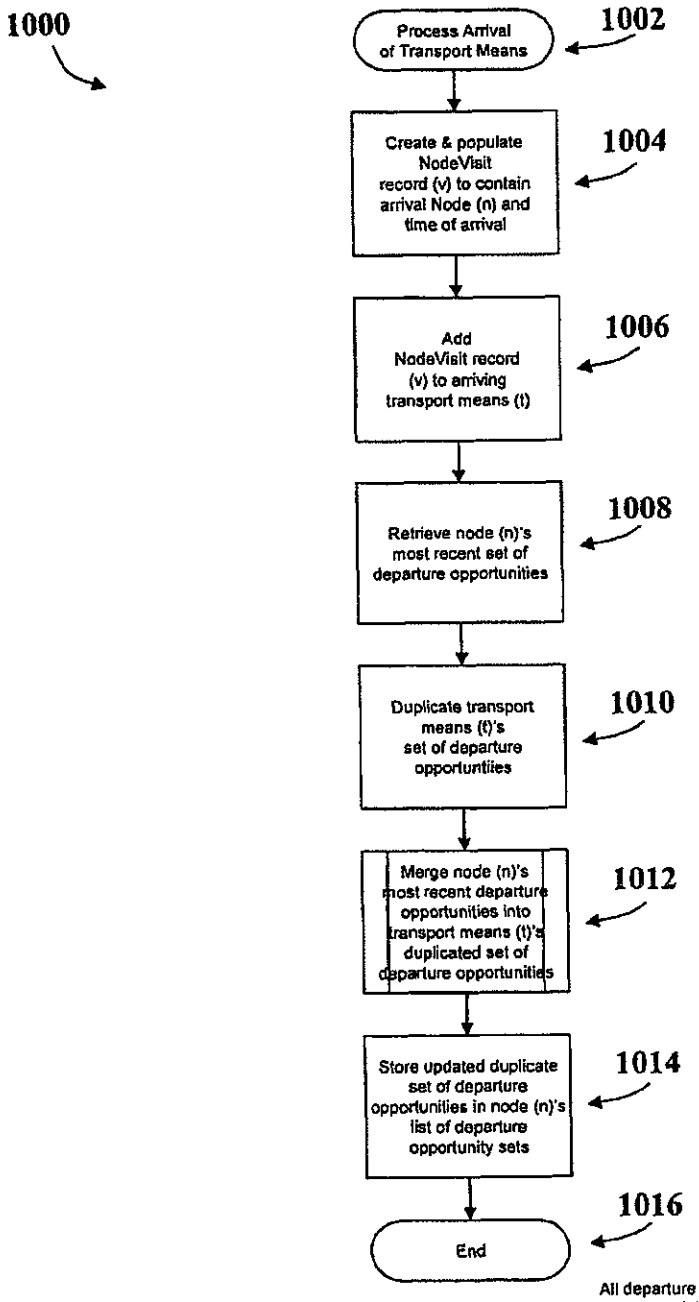

1000
Process Arrival of Transport Means
1002
Create & populate NodeVisit record (v) to contain arrival Node (n) and time of arrival
1004
Add NodeVisit record (v) to arriving transport means (t)
1006
Retrieve node (n)'s most recent set of departure opportunities
1008
Duplicate transport means (t)'s set of departure opportunities
1010
Merge node (n)'s most recent departure opportunities into transport means (t)'s duplicated set of departure opportunities
1012
Store updated duplicate set of departure opportunities in node (n)'s list of departure opportunity sets
1014
End
1016
All departure times in a departure opportunities record are initialised to zero by default.

Figure 10

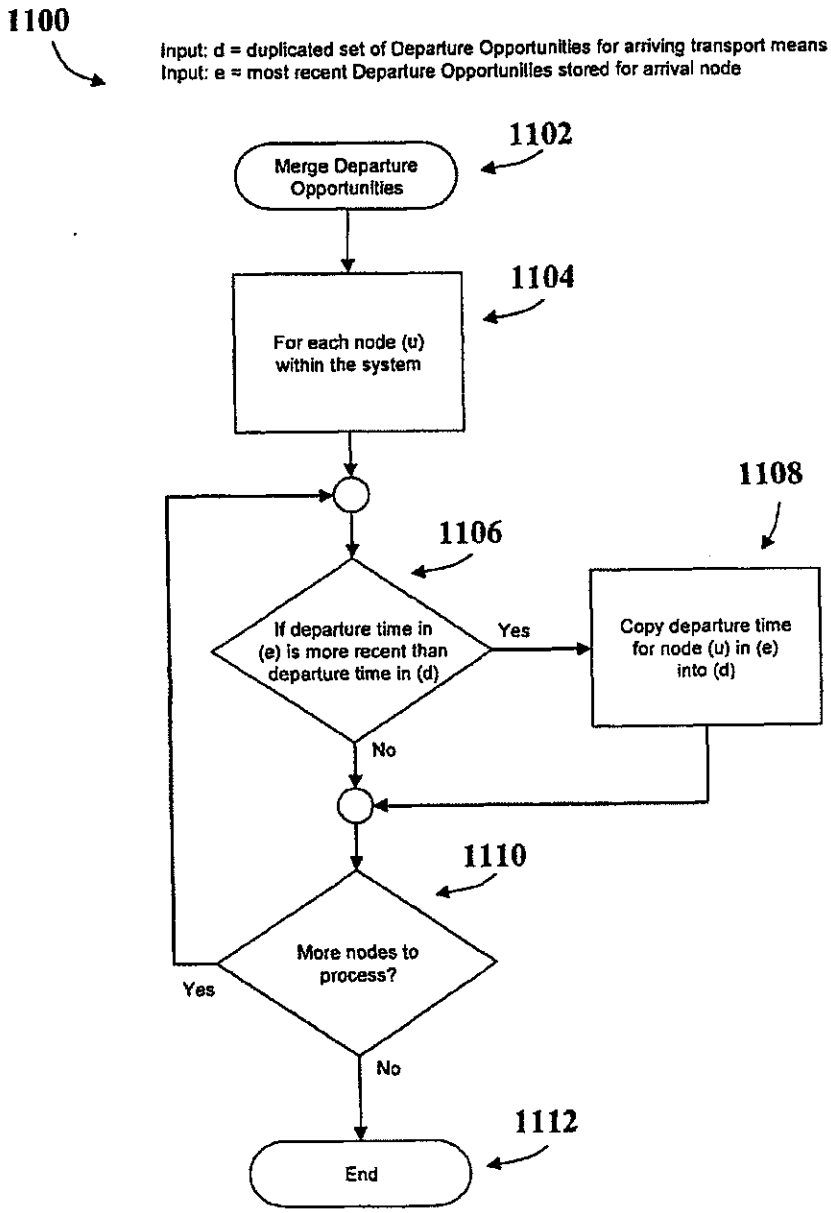

1100
Input: d = duplicated set of Departure Opportunities for arriving transport means
Input: e = most recent Departure Opportunities stored for arrival node
1102
Merge Departure Opportunities
1104
For each node (u) within the system
1108
1106
If departure time in (e) is more recent than departure time in (d)
Yes
Copy departure time for node (u) in (e) into (d)
No
1110
More nodes to process?
Yes
No
1112
End

Figure 11

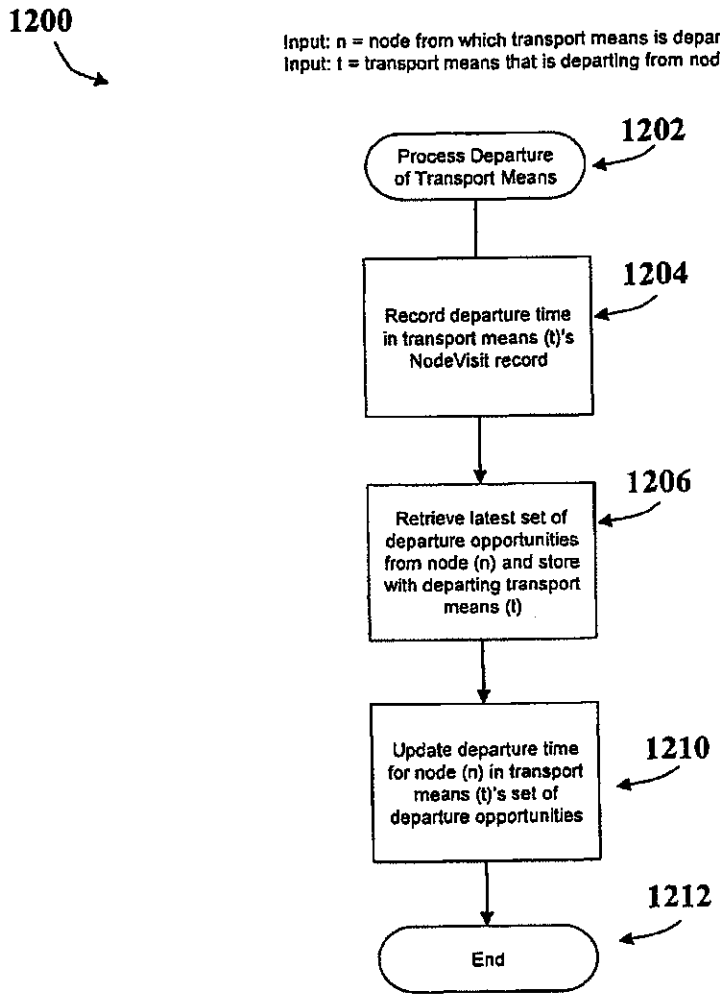

1200
Input: n = node from which transport means is departing
Input: t = transport means that is departing from node s
Process Departure of Transport Means
1202
Record departure time in transport means (t)'s NodeVisit record
1204
Retrieve latest set of departure opportunities from node (n) and store with departing transport means (t)
1206
Update departure time for node (n) in transport means (t)'s set of departure opportunities
1210
End
1212

Figure 12

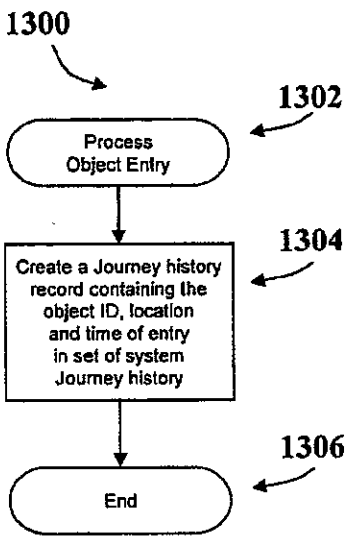


Figure 13a

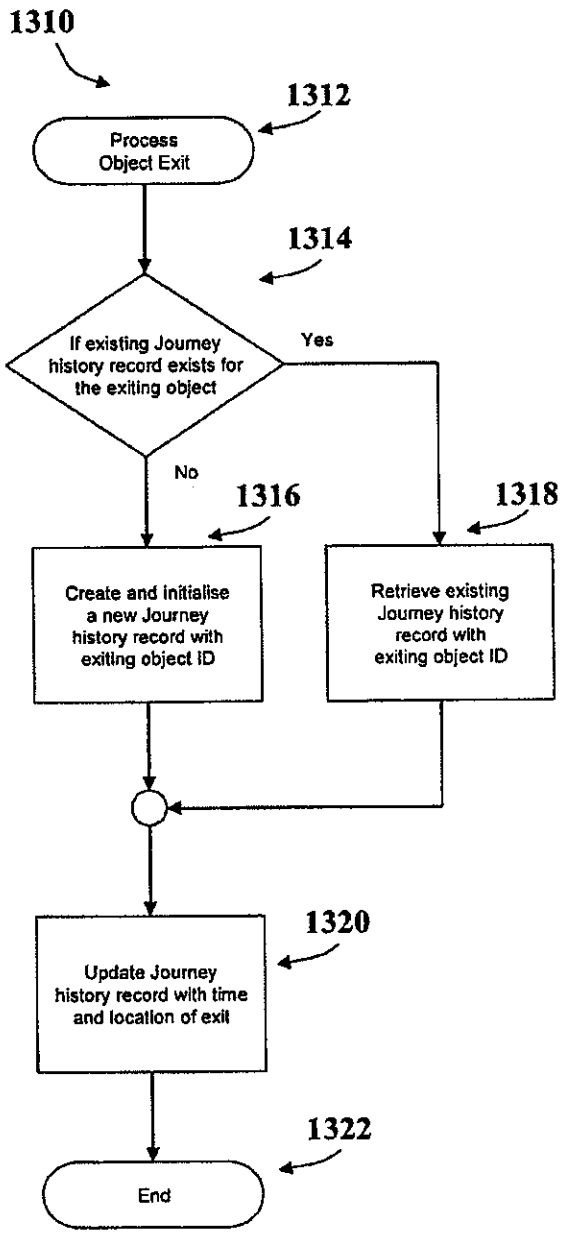


Figure 13b

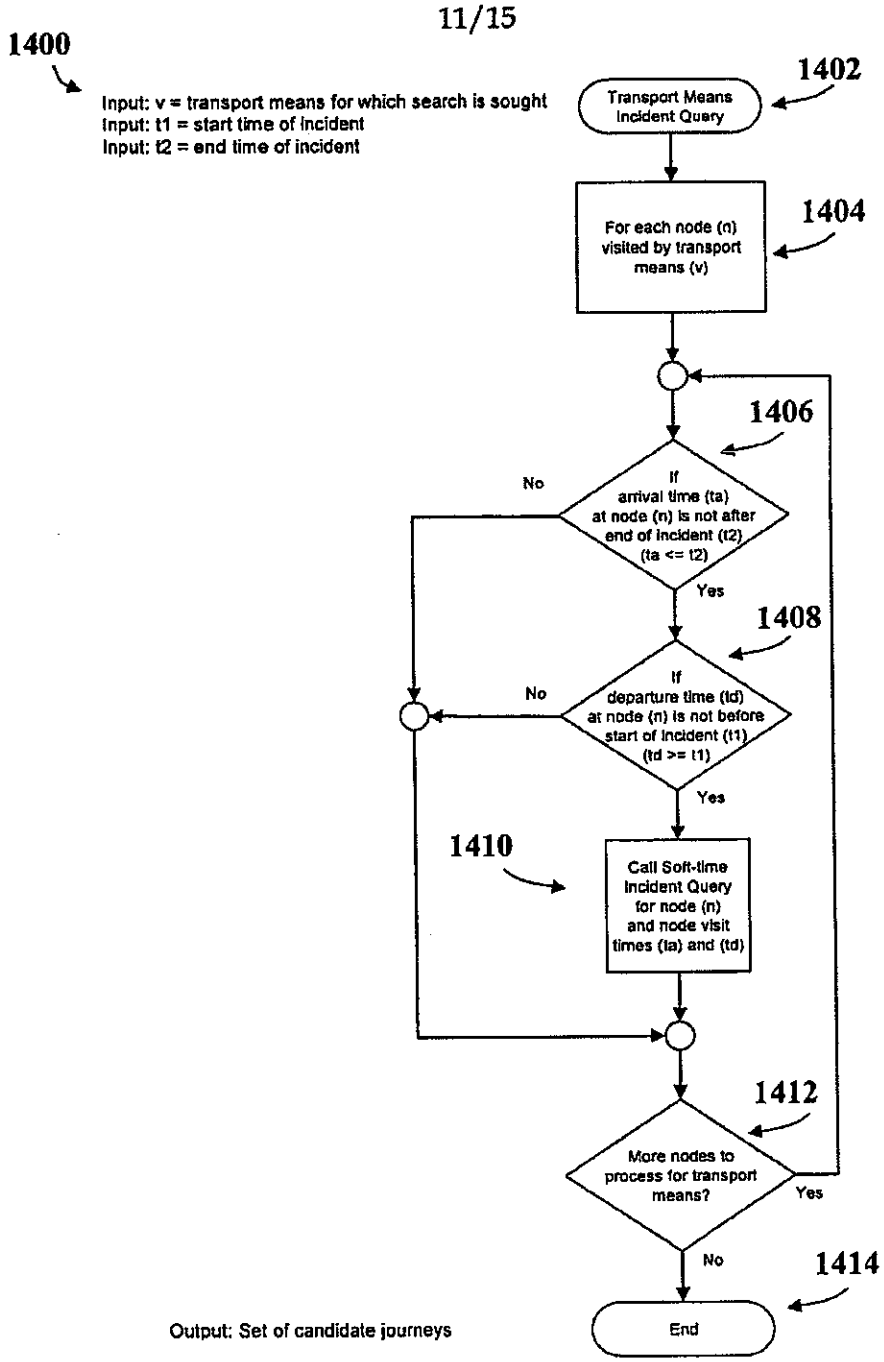

1400
Input: v = transport means for which search is sought
Input: t1 = start time of incident
Input: t2 = end time of incident
1402
Transport Means Incident Query
For each node (n) visited by transport means (v)
1404
1406
If arrival time (ta) at node (n) is not after end of incident (t2) (ta <= t2)
No
Yes
1408
If departure time (td) at node (n) is not before start of incident (t1) (td >= t1)
No
Yes
1410
Call Soft-time Incident Query for node (n) and node visit times (ta) and (td)
1412
More nodes to process for transport means?
Yes
No
1414
End
Output: Set of candidate journeys

Figure 14

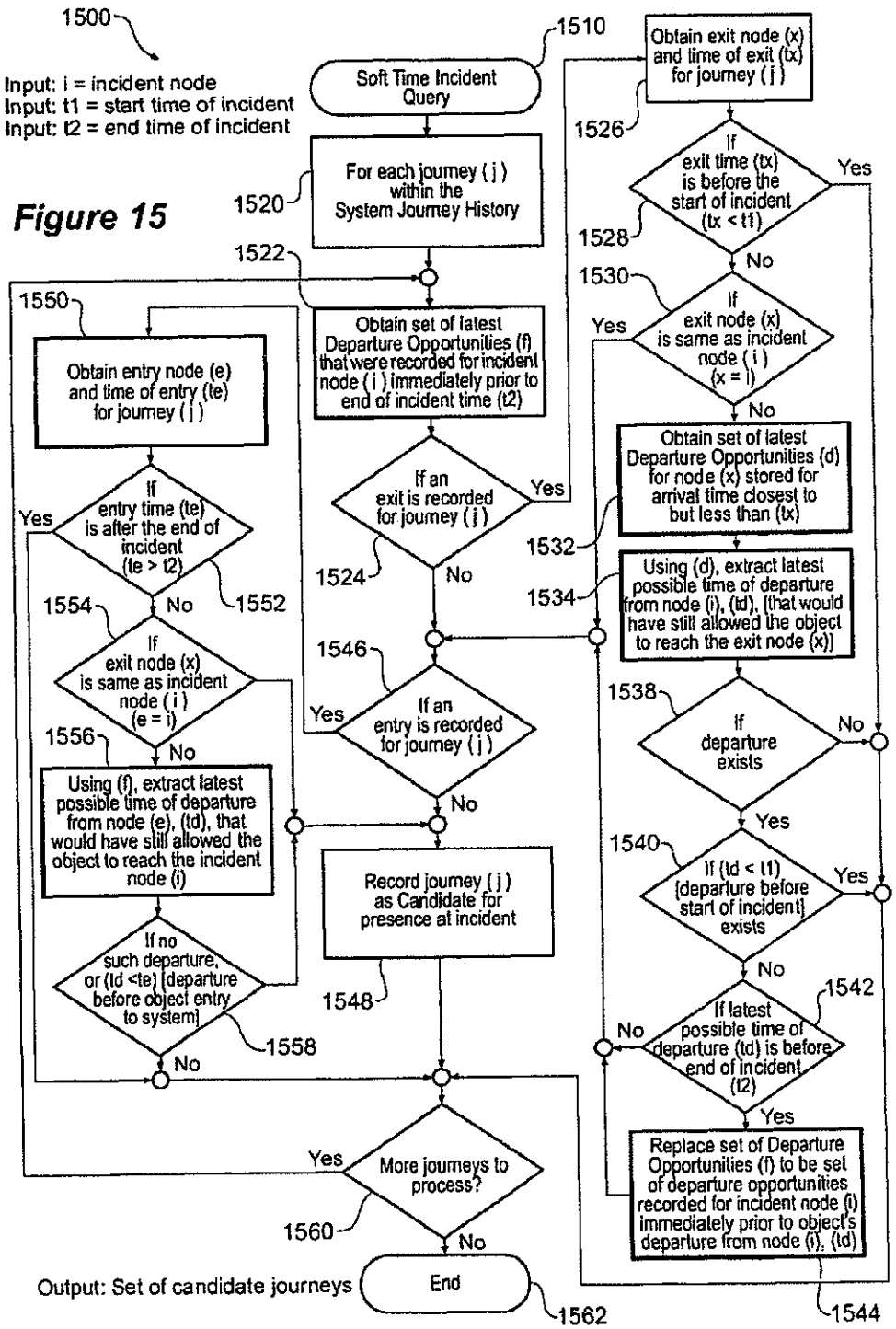

1500
Input: i = incident node
Input: t1 = start time of incident
Input: t2 = end time of incident
Soft Time Incident Query
1510
For each journey (j) within the System Journey History
1520
1522
Obtain set of latest Departure Opportunities (f) that were recorded for incident node (i) immediately prior to end of incident time (t2)
If an exit is recorded for journey (j)
Yes
No
1524
Obtain exit node (x) and time of exit (tx) for journey (j)
1526
If exit time (tx) is before the start of incident (tx < t1)
Yes
No
1528
If exit node (x) is same as incident node (i) (x = i)
Yes
No
1530
Obtain set of latest Departure Opportunities (d) for node (x) stored for arrival time closest to but less than (tx)
1532
Using (d), extract latest possible time of departure from node (i), (td), [that would have still allowed the object to reach the exit node (x)]
1534
If departure exists
Yes
No
1538
If (td < t1) [departure before start of incident] exists
Yes
No
1540
If latest possible time of departure (td) is before end of incident (t2)
Yes
No
1542
Replace set of Departure Opportunities (f) to be set of departure opportunities recorded for incident node (i) immediately prior to object's departure from node (i), (td)
1544
1546
If an entry is recorded for journey (j)
Yes
No
Record journey (j) as Candidate for presence at incident
1548
1550
Obtain entry node (e) and time of entry (te) for journey (j)
If entry time (te) is after the end of incident (te > t2)
Yes
No
1552
1554
If exit node (x) is same as incident node (i) (e = i)
No
1556
Using (f), extract latest possible time of departure from node (e), (td), that would have still allowed the object to reach the incident node (i)
If no such departure, or (td <te) [departure before object entry to system]
1558
No
More journeys to process?
Yes
No
1560
Output: Set of candidate journeys
End
1562

Figure 15

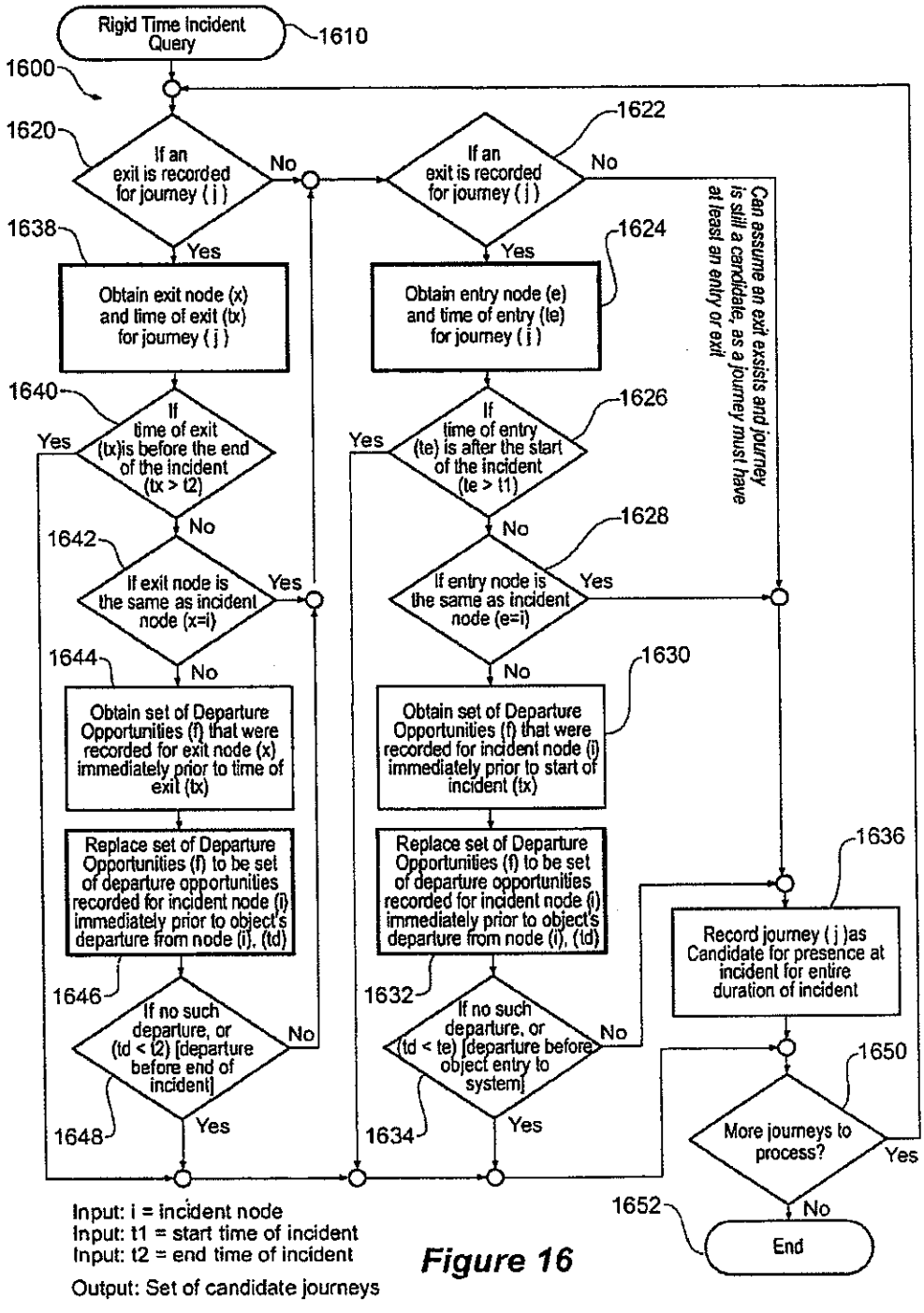

Rigid Time Incident Query
1610
1600
1620
If an exit is recorded for journey (j)
No
Yes
1638
Obtain exit node (x) and time of exit (tx) for journey (j)
1640
If time of exit (tx)is before the end of the incident (tx > t2)
Yes
No
1642
If exit node is the same as incident node (x=i)
Yes
No
1644
Obtain set of Departure Opportunities (f) that were recorded for exit node (x) immediately prior to time of exit (tx)
Replace set of Departure Opportunities (f) to be set of departure opportunities recorded for incident node (i) immediately prior to object's departure from node (i), (td)
1646
If no such departure, or (td < t2) [departure before end of incident]
No
Yes
1648
1622
If an exit is recorded for journey (j)
No
Yes
1624
Obtain entry node (e) and time of entry (te) for journey (j)
1626
If time of entry (te) is after the start of the incident (te > t1)
Yes
No
1628
If entry node is the same as incident node (e=i)
Yes
No
1630
Obtain set of Departure Opportunities (f) that were recorded for incident node (i) immediately prior to start of incident (tx)
Replace set of Departure Opportunities (f) to be set of departure opportunities recorded for incident node (i) immediately prior to object's departure from node (i), (td)
1632
If no such departure, or (td < te) [departure before object entry to system]
No
Yes
1634
Can assume an exit exists and journey is still a candidate, as a journey must have at least an entry or exit
1636
Record journey (j)as Candidate for presence at incident for entire duration of incident
1650
More journeys to process?
Yes
No
1652
End
Input: i = incident node
Input: t1 = start time of incident
Input: t2 = end time of incident
Output: Set of candidate journeys

Figure 16

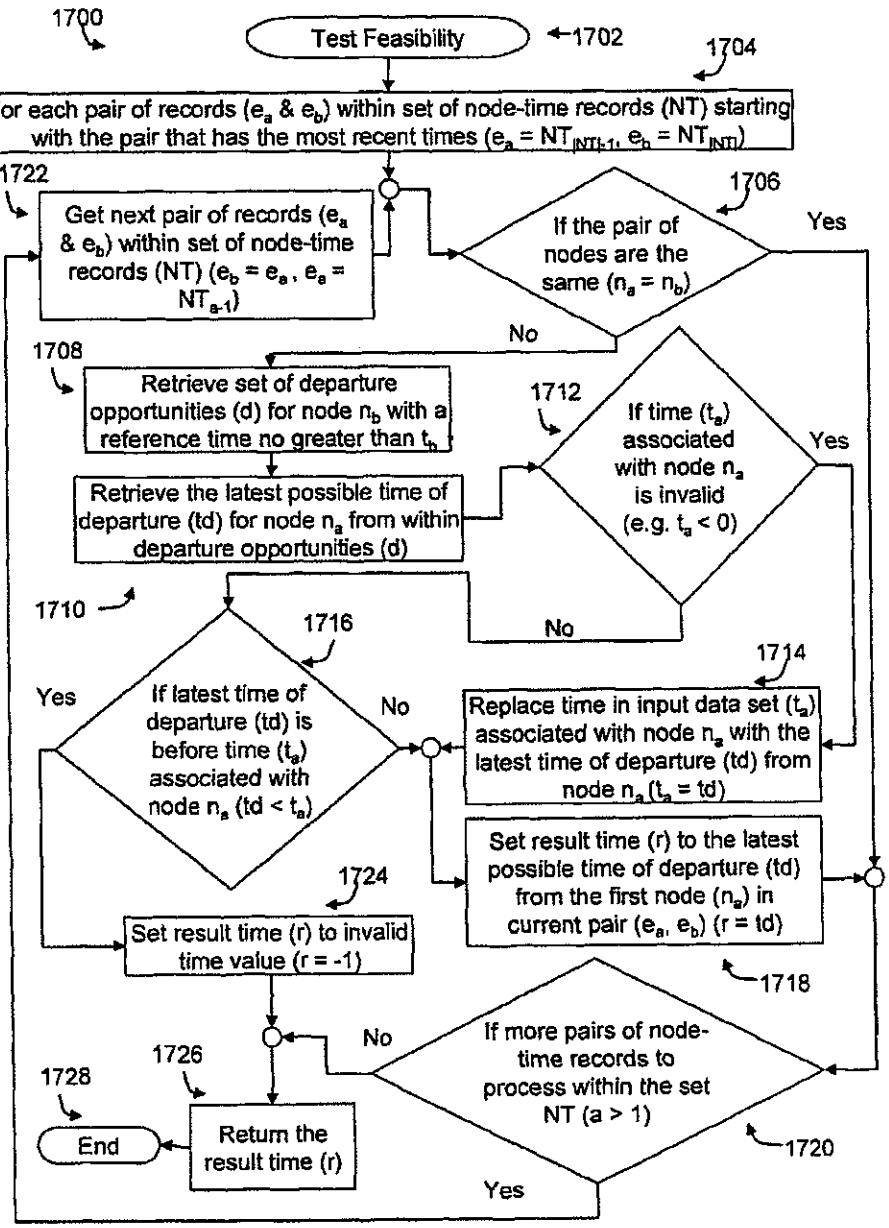

1700
Test Feasibility
1702
1704
For each pair of records (e_a & e_b) within set of node-time records (NT) starting with the pair that has the most recent times ($e_a = NT_{|NT|-1}$, $e_b = NT_{|NT|}$)
1722
Get next pair of records (e_a & e_b) within set of node-time records (NT) ($e_b = e_a$, $e_a = NT_{a-1}$)
1706
If the pair of nodes are the same ($n_a = n_b$)
Yes
No
1708
Retrieve set of departure opportunities (d) for node n_b with a reference time no greater than t_b
Retrieve the latest possible time of departure (td) for node n_a from within departure opportunities (d)
1712
If time (t_a) associated with node n_a is invalid (e.g. $t_a < 0$)
Yes
No
1710
1716
If latest time of departure (td) is before time (t_a) associated with node n_a ($td < t_a$)
Yes
No
1714
Replace time in input data set (t_a) associated with node n_a with the latest time of departure (td) from node n_a ($t_a = td$)
Set result time (r) to the latest possible time of departure (td) from the first node (n_a) in current pair (e_a, e_b) (r = td)
1724
Set result time (r) to invalid time value (r = -1)
1718
If more pairs of node-time records to process within the set NT (a > 1)
No
Yes
1720
1726
1728
End
Return the result time (r)

Figure 17

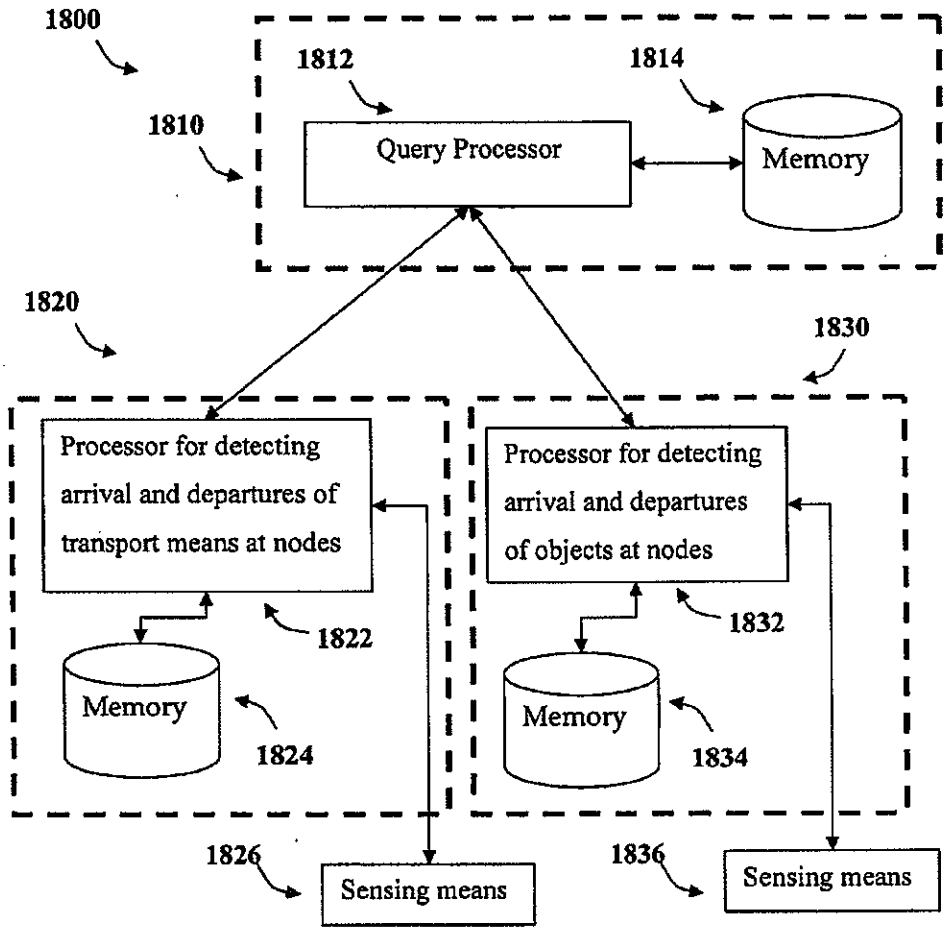

1800
1812
1814
1810
Query Processor
Memory
1820
1830
Processor for detecting arrival and departures of transport means at nodes
Processor for detecting arrival and departures of objects at nodes
1822
1832
Memory
Memory
1824
1834
1826
1836
Sensing means
Sensing means

Figure 18