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CA 2794990 A1 2013/06/27

(21) **2 794 990**

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(22) Date de dépôt/Filing Date: 2012/11/07

(41) Mise à la disp. pub./Open to Public Insp.: 2013/06/27

(30) Priorité/Priority: 2011/12/27 (EP11195820.3)

(51) Cl.Int./Int.Cl. *G08G 1/01* (2006.01), *G08G 1/052* (2006.01)

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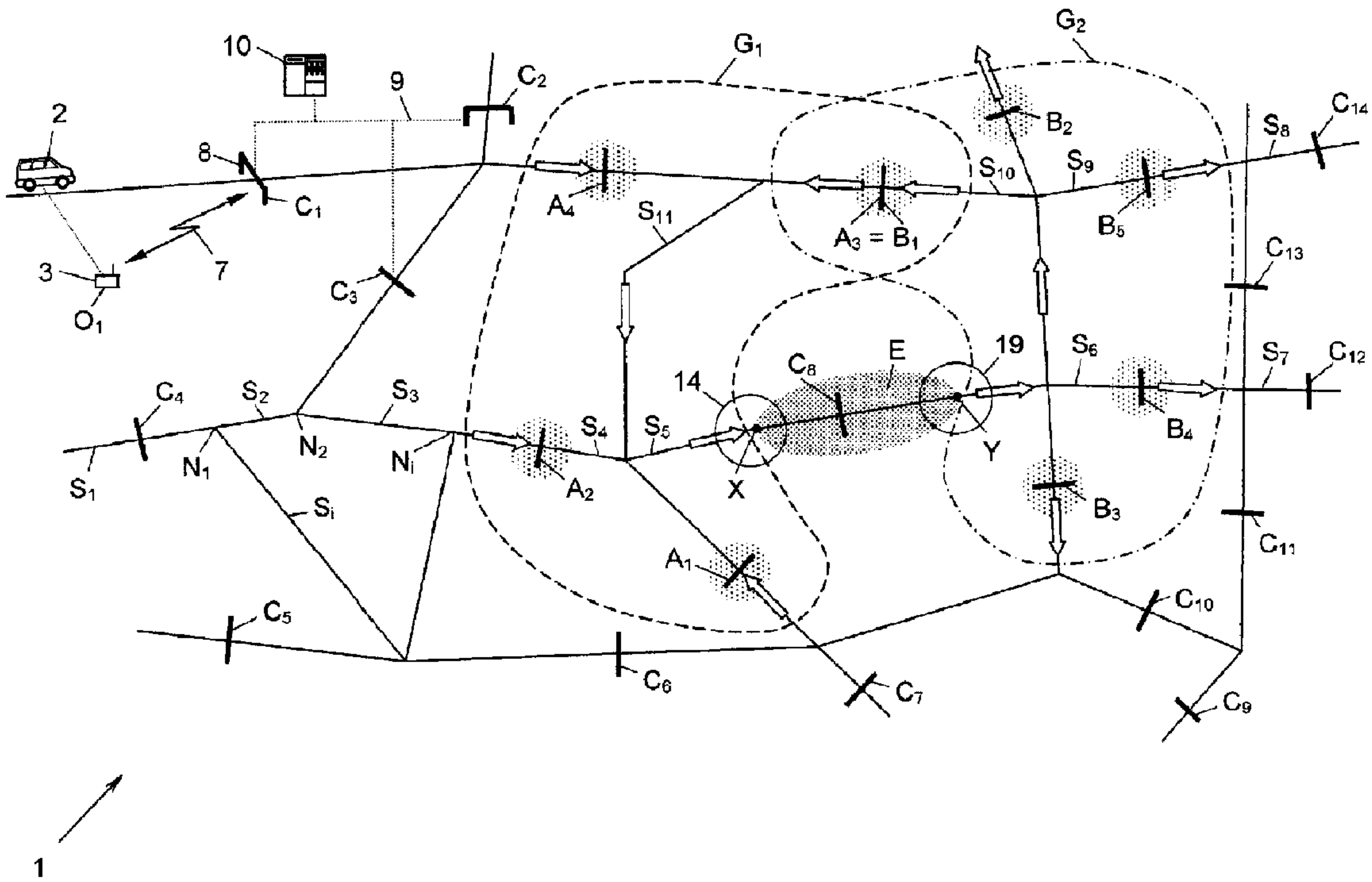
(54) Titre : PROCEDE POUR DETERMINER DES DONNEES D'ECOULEMENT DE LA CIRCULATION DANS UN RESEAU ROUTIER

(54) Title: METHOD FOR DETERMINING TRAFFIC FLOW DATA IN A ROAD NETWORK



(57) Abrégé/Abstract:

Method for determining traffic flow data in a road network with road segments of which at least some are equipped with radio beacons for DSRC radio communication with vehicle-mounted on-board units, which can determine their position and can record measurement data of their vehicle or their environment, including passing a first radio beacon and receiving a request message, which includes a start location and a stop location, from the first radio beacon via a first DSRC radio communication; ongoing determining the own position and, once the own position enters into a given close range of the start loca- tion, starting the recording of the measurement data; once the own position enters into a given close range of the stop location, stopping the recording of the measurement data; and transmitting the recorded measurement data to the next radio beacon which is passed by the on-board unit via a second DSRC radio communication.

Abstract:

Method for determining traffic flow data in a road network with road segments of which at least some are equipped with radio beacons for DSRC radio communication with vehicle-mounted on-board units, which can determine their position and can record measurement data of their vehicle or their environment, including passing a first radio beacon and receiving a request message, which includes a start location and a stop location, from the first radio beacon via a first DSRC radio communication; ongoing determining the own position and, once the own position enters into a given close range of the start location, starting the recording of the measurement data; once the own position enters into a given close range of the stop location, stopping the recording of the measurement data; and transmitting the recorded measurement data to the next radio beacon which is passed by the on-board unit via a second DSRC radio communication.

Method for Determining Traffic Flow Data in a Road Network

The present invention relates to a method for determining traffic flow data in a road network.

The term "traffic flow data" as used in this specification means all types of sensor and measurement data from and relating to vehicles of moving and stationary traffic that can be collected on the level of granularity of individual vehicles and can provide an overview of the traffic situation, the "traffic flow" in a road network or a section thereof in the form of an, e.g., statistical analysis over several vehicles.

Modern vehicles have a variety of sensors for the generation of measurement data, such as speed, acceleration and deceleration, data from the ABS and ESP systems of the vehicle, status of the lighting and heating systems, environmental and weather data such as daylight, outside temperature, air humidity, visibility (fog), data from camera and radar systems of the vehicle for detecting the surrounding traffic and hazards, etc. The multitude of measurement data from the vehicle is further increased by measurement data of electronic accessory devices ("on-board units", OBUs), e.g. satellite navigation receivers and/or transceivers for radio communication with roadside radio beacons ("Roadside Units", RSUs). Such on-board units can receive measurement data of the vehicle as well as, by means of own sensors, acquire measurement data relating to the vehicle and/or its environment, e.g. positions and speeds measured by means of satellite navigation from radio communications with radio beacons or mobile networks, environmental data from own weather sensors, etc.

However, determining meaningful traffic flow data is a non-trivial problem in practice even with vehicles equipped as such. A transmission of the measurement data of all vehicles to a central analysis unit is not realistic due to the big data volume and the limited transmission capacities of currently available wireless channels e.g. of mobile radio systems. Moreover, the measurement data generated by the individual vehicles are highly redundant in dense traffic and of little use with "fair weather conditions" (low traffic, good weather, no incidents or accidents). Therefore, present systems for collecting traffic flow data only use a limited number of specially equipped vehicles, e.g. taxis, which go with the flow of the traffic to provide a representative picture of the traffic situation or the environmental situation. However, this firstly requires a special fleet of vehicles, and secondly requires a permanent data link from these vehicles to the analysis center, normally a data link to a wireless network, which is expensive and requires many resources.

The technical report ETSI TR 102 898 "Machine to Machine Communications (M2M); Use cases of Automotive Applications in M2M capable networks", V 0.4.0, September 2010, Chapter 5.2.3, describes scenarios for traffic information services which distribute information from a central unit via wireless networks to OBUs, which in turn send traffic flow data to the central unit in the case of specific events. This design can be attributed to the aforementioned non-specific data collection solutions having the disadvantage of an uncontrollable high amount of data without any possibility of a location-specific access to the data-generating vehicles in the collection process.

In contrast to this prior art, the invention aims at creating a method for collecting traffic flow data, which overcomes the said disadvantages.

This aim is achieved according to the invention by using a method for determining traffic flow data in a road network having road segments of which at least some are equipped with radio beacons for DSRC (Dedicated Short Range Communications) with vehicle-mounted on-board units, which are configured to determine their position and record measurement data of their vehicle or their environment, comprising the following steps carried out by an on-board unit:

a) passing a first radio beacon and receiving a request message, which at least includes a start location and a stop location, from the first radio beacon via a first DSRC radio communication;

b) ongoing determining the own position and, once the own position enters into a given close range of the start location, starting the recording of the measurement data;

c) ongoing determining the own position and, once the own position enters into a given close range of the stop location, stopping the recording of the measurement data; and

d) transmitting the recorded measurement data to the next radio beacon which is passed by the on-board unit along its way via a second DSRC radio communication.

The method according to the invention uses the location-based infrastructure of a network of Roadside Units as is currently already used for example in road toll, traffic telematics and/or vehicle communication systems and is based on dedicated short range communications (DSRC) between vehicle-mounted OBUs and RSUs. The limited range of such DSRC radio communications permits a location-specific feed of requests for data collection into a subset of the road users of the road network, namely all vehicles moving between a start location and a stop location and serving as data sources for the determination of the traffic flow data. In this connection, the collection area is not bound to the locations of the particular RSUs, but will be defined by the self-localization of the OBUs. As a result, comprehensive, nearly continuous traffic flow data from a specific area of a wide road network can be acquired with the lowest possible storage requirements and the lowest possible load on the available communication channels, i.e. limited to DSRC radio communications between OBUs and RSUs around the collection area.

According to a further aspect of the invention, a method for determining traffic flow data which uses a multitude of on-board units, each of which carries out the aforementioned steps a) to d), also includes the following steps:

determining those radio beacons that are the last in all possible access routes to the start location formed by the road segments of the road network, as a first group of radio beacons;

providing the request message to the radio beacons of the first group; and

transmitting the request message from each radio beacon of the first group to all on-board units or to at least a subset of the on-board units while passing such radio beacon according to step a).

Where a subset of the passing on-board units is used, the subset is appropriately defined as a representative selection, e.g. every second, third, tenth, hundredth, etc., of the passing on-board units.

The method of the invention can be triggered peripherally in a radio beacon where the request message is compiled and distributed to the radio beacons of the first group. However, the request message is preferably compiled in a central unit interconnected with the radio beacons and is sent by the central unit to the radio beacons of the first group for providing. This e.g. allows a traffic control at all times to get a detailed view of the traffic situation in a section of the road network.

For this purpose it is particularly advantageous, if according to a further preferred the method comprises the following additional steps:

selecting a radio beacon as a data-collecting radio beacon; and

forwarding the measurement data emitted by on-board units in their step d) from the particular receiving radio beacon to the data-collecting radio beacon.

In order to keep the data traffic between the radio beacons to a minimum, the data-collecting radio beacon is set up as near as possible to the collection area, preferably by applying these additional steps:

determining those radio beacons that are the first in all possible exit routes from the stop location formed by the road segments of the road network, as a second group of radio beacons; and

selecting the data-collecting radio beacon from the second group.

In the version comprising the central analysis of the method, the measurement data is preferably sent by the data-collecting radio beacon to the central unit for analysis.

In order to further reduce the data traffic between the data-collecting radio beacon and the central unit, a further advantageous feature of the invention provides for the measurement data to be pre-analyzed and compressed by the data-collecting radio beacon before being sent to the central unit for analysis.

In every embodiment of the method of the invention, the request message can preferably also include a specification of a type of measurement data to be recorded, while the on-board unit only records measurement data of such type, and/or the request message can also include a specification of a period of validity, while the on-board unit only records measurement data within such period of validity. This permits to further specify the requests for data collection, which allows an even more exact view of the traffic situation. The radio beacon can also interrogate an on-board unit before sending the request message to retrieve the type of measurement data collected by the on-board unit and to adapt the request message accordingly.

Further features and advantages of the invention follow from the following description of a preferred embodiment which refers to the accompanying drawings in which:

Fig. 1 shows a schematic depiction of a road network with components used by the method of the invention;

Fig. 2 shows a block diagram of one of the on-board units of the road network of Fig. 1;

Fig. 3 shows a flow chart of one of the processes running in the on-board unit of Fig. 2;

Fig. 4 shows a flow chart of one of the processes running in the road network von Fig. 1; and

Fig. 5 shows the structure of a request message for data collection in the processes of Fig. 3 and Fig. 4.

In Fig. 1, we see a schematic depiction of a road network 1 consisting of a multitude of road segments S_1, S_2, S_3, …, generally S_i, between which connection points or nodes N_1, N_2, N_3, …, generally N_i, are located. Accordingly, the road network 1 can be modeled or depicted by a corresponding network graph, as is known in the prior art. It is understood that own road segments S_i can be defined for different lanes and/or directions of travel in the road network 1.

In the road network 1, there is moving a multitude of vehicles 2 (of which only one is exemplarily shown) each of which is equipped with an on-board unit (OBU) 3, here identified by the designations O_1, O_2, O_3, …, generally O_i. In addition to a micro-processor 4 and a storage 5, each OBU 3 has a short-range transceiver 6 (Fig. 2) via which the OBU can handle dedicated short range communications (DSRC) 7 with radio beacons 8 of the road toll systems 1.

The radio beacons 8 are locally distributed across the entire road network 1 and are designated in this example as A_1, A_2, A_3, ..., generally A_i, B_1, B_2, B_3, ..., generally Bi, and C_1, C_2, C_3, ..., generally C_i. The radio beacons 8 are each installed as Road Side Units (RSUs) at a road segment S_i, whereby also several radio beacons 8 can be installed at a road segment S_i or one radio beacon 8 can cover several road segments S_i.

The radio beacons 8 are interconnected e.g. via a wired data network 9 and can also be interconnected via this data network with a central unit 10 of the road network 1, for example a traffic control or toll charger (TC).

Due to the short range of the radio communications 7 between OBUs 3 and radio beacons 8, the vehicles 2 passing a radio beacon 8 can be localized on the location or radio coverage range of this radio beacon 8. The radio beacons 8 are, for example, part of a road toll system in which they localize the movements of the vehicles 2 by means of the radio communication 7, to charge the vehicles 2 for passing toll roads accordingly. Further applications of the radio beacons 8 e.g. are the distribution of traffic information or "infotainment" to passing vehicles 2 and/or the reception of data of the passing vehicles 2.

The radio communications 7, i.e. notably the transceivers 6 of the OBUs 3 and the radio beacons 8, may work according to every short range wireless standard as is known in the prior art, such as the DSRC standards ITS-G5, IEEE 802.11p, WAVE (wireless access in a vehicle environment), WLAN (wireless local area network), RFID (radio frequency identification), Bluetooth®, etc. The radio range of the radio communication 7 (and the radio coverage range of the radio beacons 8) usually is some 10 to some 100 meters, but specifically with WLAN, WAVE and IEEE 802.11p can be up to some kilometers, and usually is not larger than the extension of the road segment S_i to which the radio beacon 8 is assigned, and usually does not overlap with the radio coverage range of an adjacent radio beacon 8. It is preferably as limited as possible so as to achieve a localization of the passing vehicles 2 as precisely as possible.

The described infrastructure of the road network 1 is now used to collect traffic flow data from a narrowly limited area E of the road network 1 in the following as described below.

To this end, the invention uses specifically equipped OBUs, which are explained in detail using Fig. 2 and Fig. 3. The OBUs 3 and O_i as contemplated here have the capability for both en the radio communication 7 and for autonomously locating their own position p in the road network 1, namely by means of a positioning device 11. The positioning device 11 can determine the position p of the OBU 3 for example by an optical detection of specific landmarks in camera images of its environment, by means of radio triangulation in terrestrial radio networks, by means of cell detection in mobile networks, etc. The positioning device 11 preferably is a satellite navigation receiver for a global navigation satellite system (GNSS), like GPS, GLONASS, GALILEO, etc.

Using the positioning device 11 every OBU 3 is capable of autonomously detecting when the collection area E is entered and is left. For this purpose, the collection area E is defined by its start location X on the associated road segment S_i and its stop location Y on this (or another) road segment S_i, i.e. in the example illustrated it spreads over the road segment S5 between the start location X and the stop location Y. In this respect it is irrelevant whether a radio beacon C_8 is located in the collection area E or not.

A location-specific distribution process - to be further outline below - which accesses the network of radio beacons 8 now provides every OBU 3 with a request for data collection from a radio beacon 8 in the form of a request message M (Fig. 5), which (at least) includes the start location X and the stop location Y. Fig. 3 shows the procedure triggered by such message in an OBU 3 in detail.

According to Fig. 3, in a first step 12, when passing a first radio beacon 8, the request message M is received through a (first) radio communication 7. The OBU 3 stores the start location X and the stop location Y from the request message M and from now on ongoing determines and compares its own position p with the start location X in step 13: Once the own position p gets within a (preset) close range 14 (Fig. 1) around the start location X, the data collection for the collection area E is started, i.e. a recording 14 of measurement data d is started.

The measurement data d recorded in the data collection process 14 may be of any of the abovementioned type i, for example position, speed or motion vector data d_a from the positioning device 11, temperature and weather and environmental pollution data d_b from internal weather and pollutant sensors 16 of the OBU 3, engine or exhaust data d_c or ABS or ESP data d_d of the vehicle 2, which are received from vehicle 2 via an interface module 17 having wireless or wired interfaces 18, etc.

Thus, the recording process 14 records all measurement data $d_{i,j}$ accumulated for one (or more) selected sensor and measurement data types i and stores such data in the storage 5 of the OBU 3 on an ongoing basis, i.e. continuously or at discrete times j. The selected measurement data type(s) i may be for example predefined or only forwarded in a request message M of the OBU 3.

If the request message M also includes a period of validity t, the individual OBUs 3 or O_i may also check and ensure in the recording process 14 that measurement data $d_{i,j}$ is only recorded within the period of validity t.

The collection process 14 is terminated once the positioning device 11 detects the entry into a (preset) close range 19 of the stop location Y (step 20). The close ranges 14, 19 around the start location X and the stop location Y serve as a tolerance for measuring inaccuracies of the positioning device 11 and are minimized according to the accuracy of the positioning device 11 so as to define the collection area E as accurately as possible.

Afterwards, the measurement data $d_{i,j}$ recorded in step 14 is sent in a step 21 to the next best radio beacon 8, which the OBU 3 meets on its way, via a (second) radio communication 7.

Should for any reasons the stop location Y is not detected within a preset distance from the start location X or a reasonable time, e.g. within the period of validity t, the request message M and the recorded measurement data $d_{i,j}$ may be optionally deleted in the OBU.

A large number of OBUs 3, which, when passing the collection area E, execute the procedure shown in Fig. 3, may determine traffic flow data related to the collection area E, thus creating a detailed picture of the traffic situation in the collection area 8. The execution of the data collection request necessary in step 12 and the data return in step 21 is now explained in detail by means of Fig. 4 for the entire road network von Fig. 1.

Fig. 4 shows the principle of the location-specific feed of data collection requests M into the road network 1 by means of the network of distributed radio beacons 8. The procedure starts in the central unit 10 of the network 9 of radio beacons 8, where the central unit 10 could also be realized by one of the radio beacons 8.

Given the relevant collection area E, a first group G_1 of (first) radio beacons 8, here the radio beacons A_1, A_2, A_3 and A_4, is selected in a first step 22 which serves to feed in the request messages M into the passing OBUs 3. The first group G_1 is composed of those radio beacons 8 that are the last in all possible access routes via which the start location X of the collection area E can be reached: in the example of Fig. 1, the radio beacons C_4 and A_2 are the last in the access route S_1-S_2-S_3-S_4-S_5 to the start location X, with the radio beacon A_2 being the last located in the access route. In the alternatively possible access route S_8-S_9-S_{10}-S_{11}-S_5 to the start location X, there are for example located the radio beacons C_{14}, B_5 and A_3=B_1, of which radio beacon A3=B1 is the last. Accordingly, the said radio beacons A_1, A_2, A_3=B_1 and A_4 follow as the first group G_1 over all possible access routes to the start location X.

The selection of the radio beacons 8 for the group G_1 in step 22 can for example be made by means of known algorithms of the graph theory from a network graph model of the road network 1, which is e.g. deposited in a database 23 of the central unit 10.

In a subsequent step 24, the request message M is compiled and may also include, for example, a period of validity t, e.g. in the form of an expiry time. The request message M is then distributed in step 24 by the central unit 10 via the data network 9 to all radio beacons 8 of the first group G_1, which receive this message in a receive step 25.

The radio beacons 8 and A_1, A_2, A_3, A_4 of the first group G_1 subsequently send the request message M to every OBU 3 passing them in a step 26; every OBU 3 receives the request message M in step 12 (Fig. 3).

As an option, the radio beacons 8 of the first group G_1 can send the request message M not to all, but only to a subset of the passing OBUs 3, e.g. to every second, third, tenth, hundredth, etc., passing OBU 3.

Fig. 4 shows an exemplary scenario, in which the radio beacon A_1 is consecutively passed by three OBUs O_1, O_2, O_3, while the radio beacon A2 is consecutively passed by two OBUs O_4, O_5; and the radio beacon A3 is consecutively passed by three OBUs O_6, O_7, O_8. It is understood that the send and receive steps 26, 12 each are triggered when an OBU 3 passes a radio beacon 8, i.e. at different times. As long as a radio beacon 8 of the first group G_1 does not receive an instruction to the contrary from the central unit 10, it continues with the transmission 26 of request message M to all passing OBUs 3. Such an instruction to the contrary, i.e. an request to the radio beacons 8 of the first group G_1 to stop the send step 26, can for example be issued by means of a deactivation message send by the central unit 10 to the radio beacons 8 of the first group G_1 regarding the previously sent request message M, for which purpose the request messages M can also be referenced through unique identifiers id.

Every OBU 3 (here O_1 to O_8) which has received a request message M, is carrying out the data collection process as already explained by means of Fig. 3, i.e. every OBU 3 is recording sensor data $d_{i,j}$ between the start location X and the stop location Y and delivers the recorded sensor data $d_{i,j}$ to the next radio beacon 8 on its route (step 21). All possible next radio beacons 8 that in this way can receive measurement data $d_{i,j}$ from a OBU 3 form a second group G_2 (Fig. 1).

The second group G_2 is composed of all those radio beacons 8 that are the first in the exit routes (leaving routes) from the stop location Y. For instance, in the exit route S_5-S_6-S_7 from the stop location Y, the radio beacons B_4 and C_{12} are the first with the radio beacon B_4 being the next; therefore, the radio beacon B_4 is the radio beacon to which the OBU 3 will transmit its recorded measurement data $d_{i,j}$ in the step 21. Thus, the radio beacons $B_1=A_3$, B_2, B_3, B_4, B_5 of the second group G_2 as depicted in Fig. 1 follow from all possible exit routes from the stop location Y. Fig. 4 shows the receive step 27 in the radio beacons 8 (here B_1, B_2, B_3, B_4, B_5) of the second group G_2 associated with the send step 21.

For analysis of the collected measurement data $d_{i,j}$ of all OBUs O_i, the radio beacons 8 of the second group G_2 are now sending all measurement data $d_{i,j}(O_i)$ in a send step 28 either directly to the central unit 10 or preferably - as depicted - to a selected "data-collecting" radio beacon 8 of the second group G_2, here radio beacon B_2, i.e. more precisely to a data collection process ("container") 29 in the data-collecting radio beacon B_2, which can carry out a pre-analysis and data compression of the collected measurement data $d_{i,j}(O_i)$, e.g. a statistical analysis, in an optional pre-analysis step 30. The collected and optionally pre-analyzed measurement data $d_{i,j}(O_i)$ is subsequently sent to the central unit 10 in a step 31 for final analysis 32.

The analysis in step 32 can for example determine a traffic density and/or mean traffic flow speed in the collection area E, generate traffic jam forecasts, also on the basis of weather measurement data, deceleration measurement data, etc., and generally on the basis of all aforementioned types i of the measurement data $d_{i,j}$ and its courses recorded over the time j.

The invention is not limited to the embodiments as presented, but comprises all versions and modifications covered by the appended claims.

Patent Claims:

1. A method for determining traffic flow data in a road network with road segments of which at least some are equipped with radio beacons for DSRC radio communications with vehicle-mounted on-board units, which are configured to determine their position and record measurement data of their vehicle or their environment, comprising the following steps carried out by an on-board unit:

a) passing a first radio beacon and receiving a request message, which at least includes a start location and a stop location, from the first radio beacon via a first DSRC radio communication;

b) ongoing determining the own position and, once the own position enters into a given close range of the start location, starting the recording of the measurement data;

c) ongoing determining the own position and, once the own position enters into a given close range of the stop location, stopping the recording of the measurement data; and

d) transmitting the recorded measurement data to the next radio beacon which is passed by the on-board unit along its way via a second DSRC radio communication.

2. The method according to claim 1 using a multitude of on-board units each of which carries out the steps a) to d), comprising:

determining those radio beacons that are the last in all possible access routes to the start location formed by the road segments of the road network, as a first group of radio beacons;

providing the request message to the radio beacons of the first group; and

transmitting the request message from each radio beacon of the first group to at least a subset of the on-board units passing such radio beacon according to step a).

3. The method according to claim 2, characterized in that the request message is compiled in a central unit interconnected with the radio beacons and is sent by the central unit to the radio beacons of the first group for providing.

4. The method according to claim 2, comprising:

selecting a radio beacon as a data-collecting radio beacon; and

forwarding the measurement data transmitted by on-board units in their step d) from the particular receiving radio beacon to the data-collecting radio beacon.

5. The method according to claim 4, comprising:

determining those radio beacons that are the first in all possible exit routes from the stop location formed by the road segments of the road network, as a second group of radio beacons; and

selecting the data-collecting radio beacon from the second group.

6. The method according to the claims 3 and 5, characterized in that the measurement data is sent by the data-collecting radio beacon to the central unit for analysis.

7. The method according to claim 6, characterized in that the measurement data is pre-analyzed and compressed by the da-

ta-collecting radio beacon, before the data is sent to the central unit for analysis.

8. The method according to one of the claims 1 to 7, characterized in that the request message also includes a specification of a type of measurement data to be recorded, with the on-board unit only recording measurement data of this type.

9. The method according to claim 8, characterized in that the radio beacon interrogates an on-board unit before sending the request message to retrieve the type of measurement data collected by that on-board unit, whereupon the request message is adjusted accordingly.

10. The method according to one of the claims 1 to 9, characterized in that the request message also includes a specification of a period of validity, with the on-board unit only recording measurement data within such period of validity.

11. The method according to one of the claims 1 to 10, characterized in that the own position of an on-board unit is determined by means of satellite navigation.

12. The method according to one of the claims 1 to 11, characterized in that the measurement data comprise speed and/or deceleration data of the on-board unit or its vehicle.

13. The method according to one of the claims 1 to 12, characterized in that the measurement data comprise weather data from the environment of the on-board unit or its vehicle.

14. The method according to one of the claims 1 to 13, characterized in that the measurement data comprise pollutant emission data from the environment of the on-board unit or its vehicle.

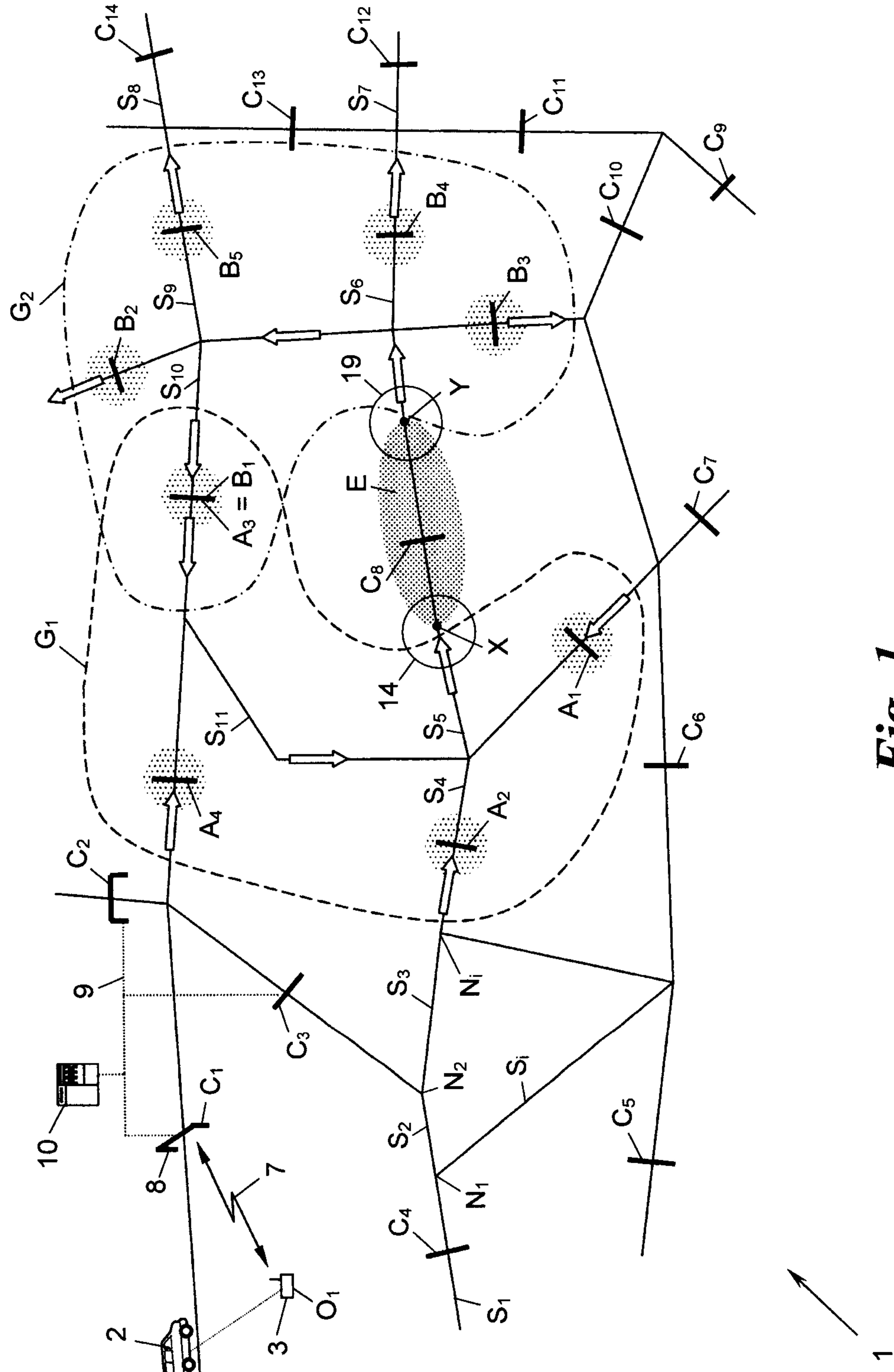

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Fig. 1

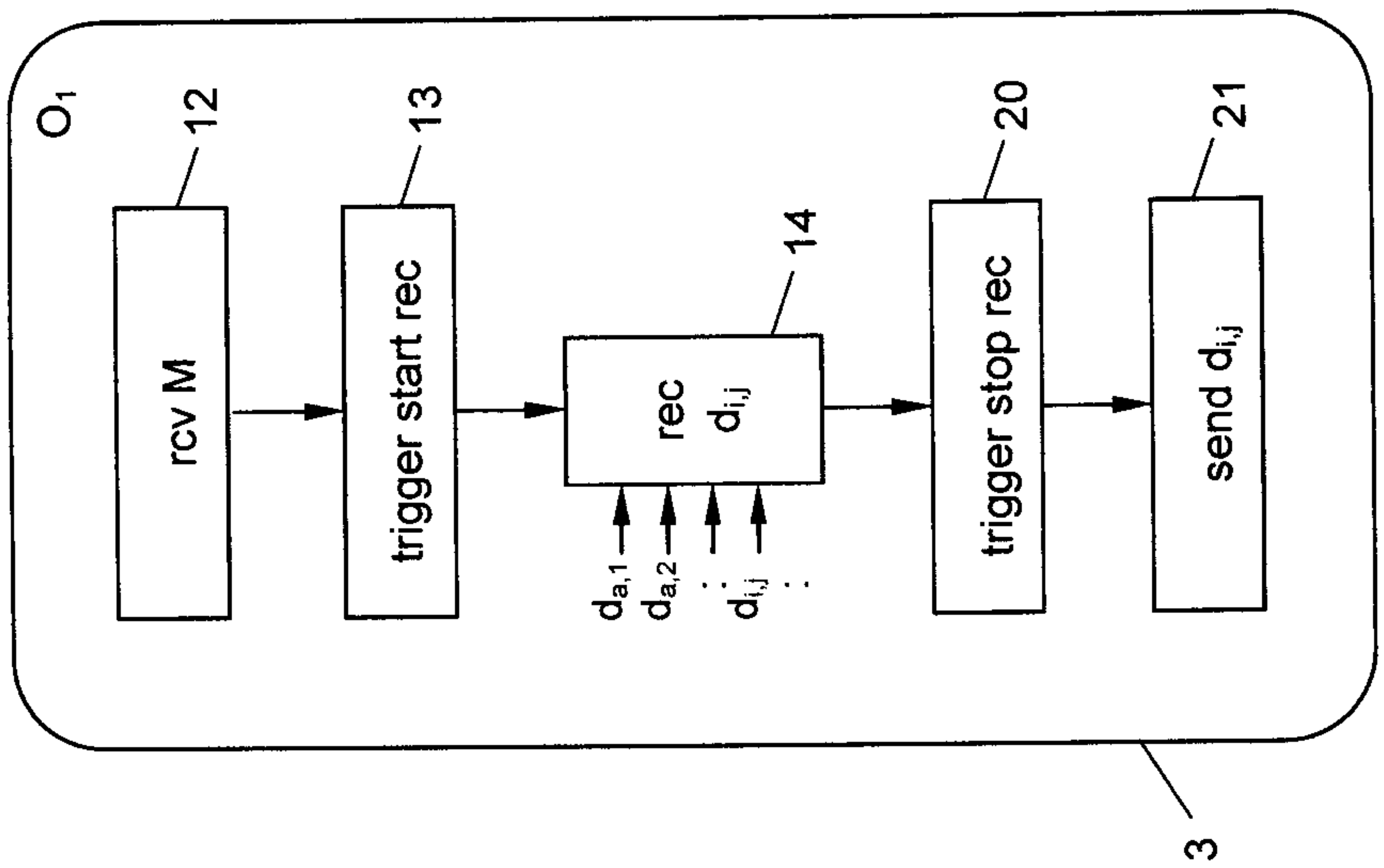


Fig. 3

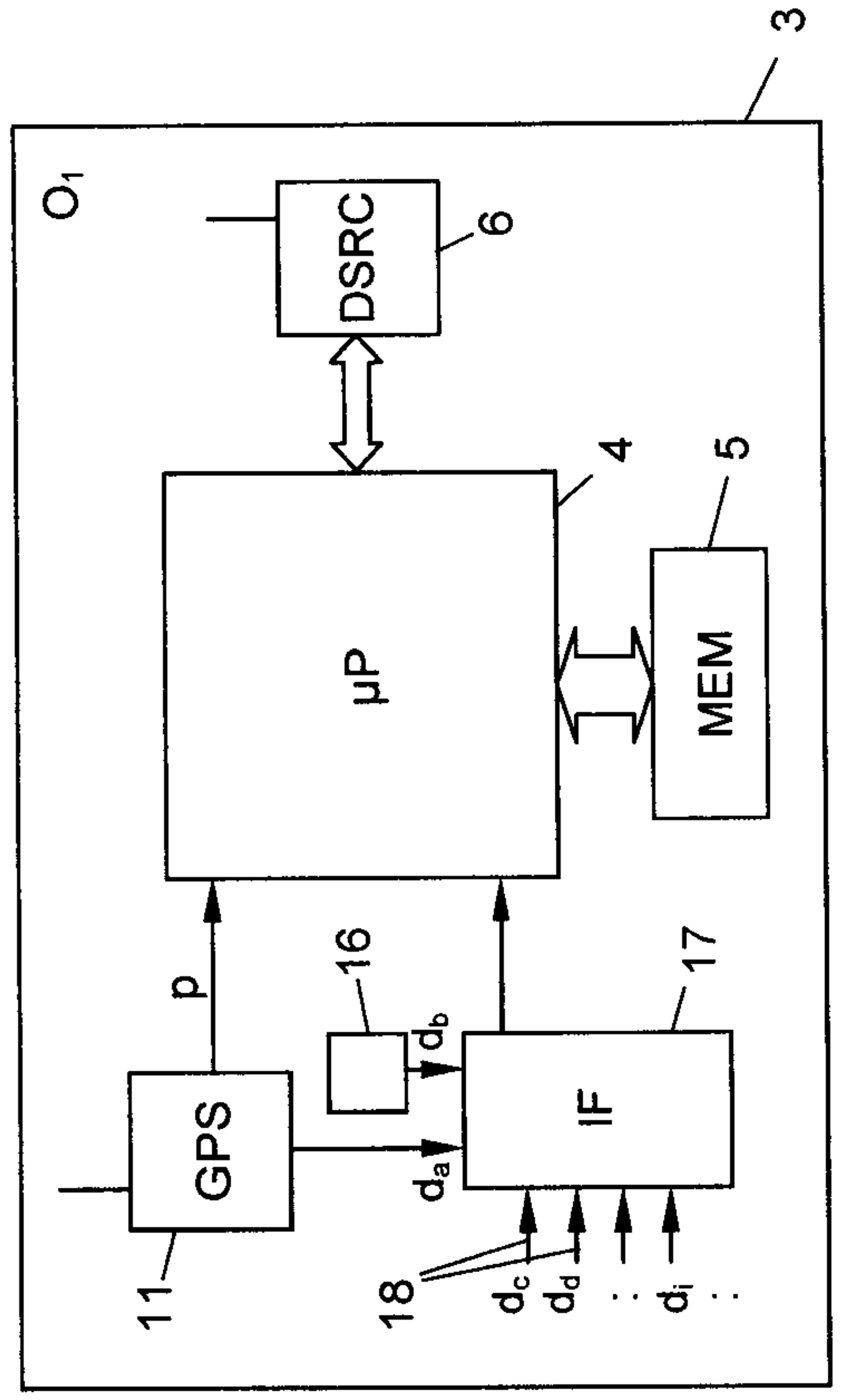


Fig. 2

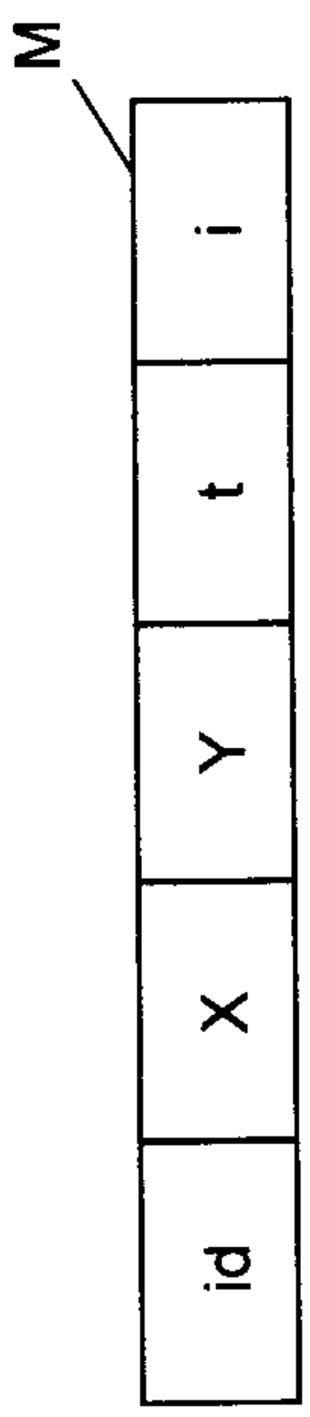
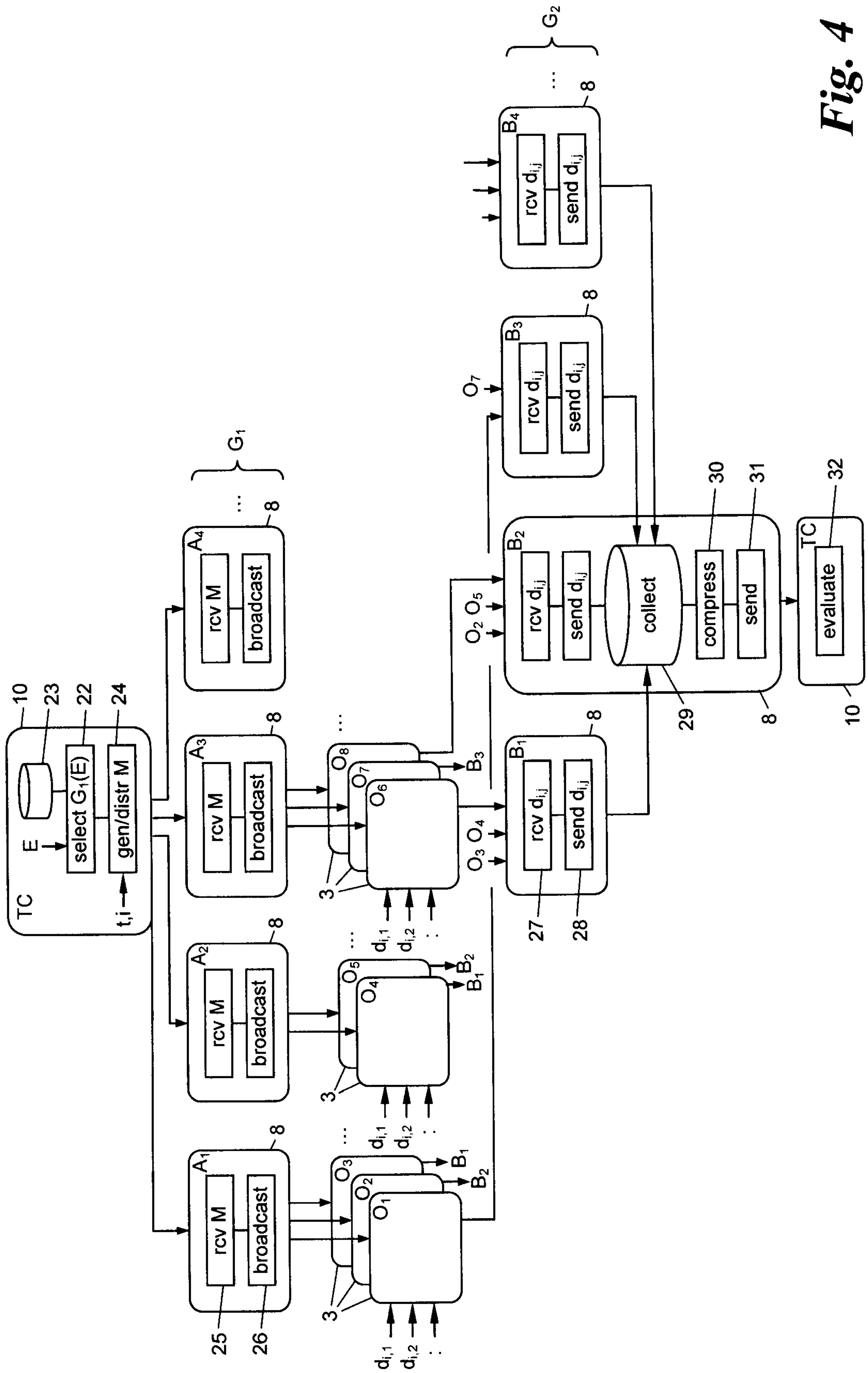


Fig. 5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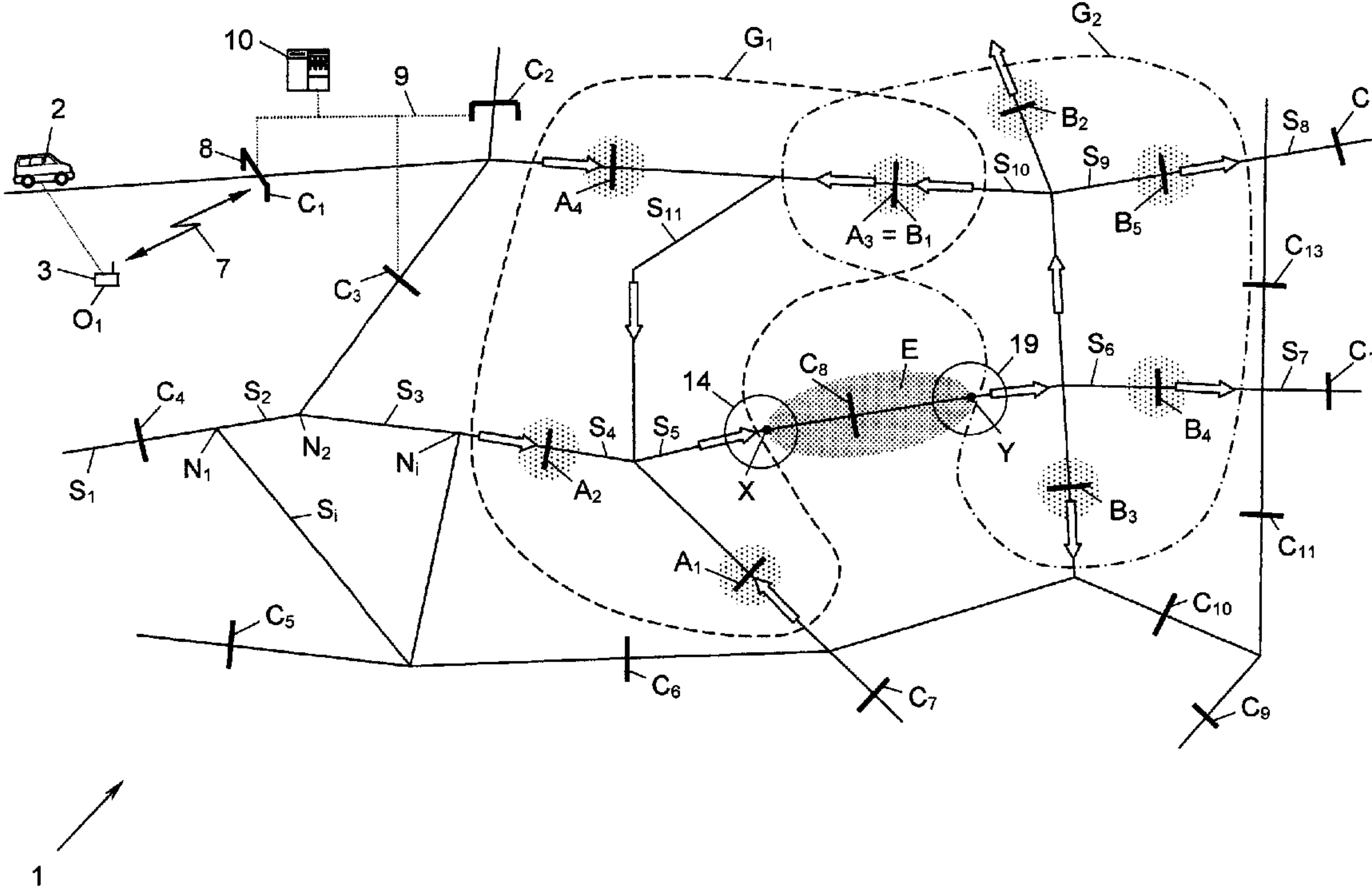
evaluate
32

Fig. 4



10
9
2
8
C1
C2
C3
3
7
O1
G1
G2
A4
S11
A3 = B1
S10
S9
B2
B5
S8
C14
C13
C12
S7
S6
19
E
C8
14
X
Y
B4
B3
C11
C10
C9
C7
C6
C5
A1
A2
S4
S5
S1
S2
S3
C4
N1
N2
Ni
Si
1