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NETWORK NODE FOR AN AD-HOC NETWORK AND PROCESS FOR PROVIDING APPLICATION SERVICES IN AN AD-HOC NETWORK

57	ABSTRACT (NOT MORE THAN 150 WORDS)
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NUMBER OF SHEETS	16
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The sheet(s) containing the abstract is/are attached.

If no classification is furnished, Form P.9 should accompany this form.
The figure of the drawing to which the abstract refers is attached.



Abstract

The invention relates to a network node (N_i) for an ad-hoc network having a plurality of network nodes (N_j) of the same type, which provide one another with application services via wireless connections (2), wherein the network node (N_i) generates a list ($LAST_i$) of all application services (S_n) provided to it by other network nodes (N_j) with associated quality classes (QEC_{in}) and makes this list ($LAST_i$) available to other network nodes (N_j) as list of the application services (S_n) provided by it with such quality classes (QEC_{in}), wherein said quality class (QEC_{in}) is at least dependent on the number of consecutive network nodes, via which the application service (S_n) is provided, and the quality class (QEC_{jn}) specified by the last of these network nodes. The invention also relates to a process for providing application services in an ad-hoc network.

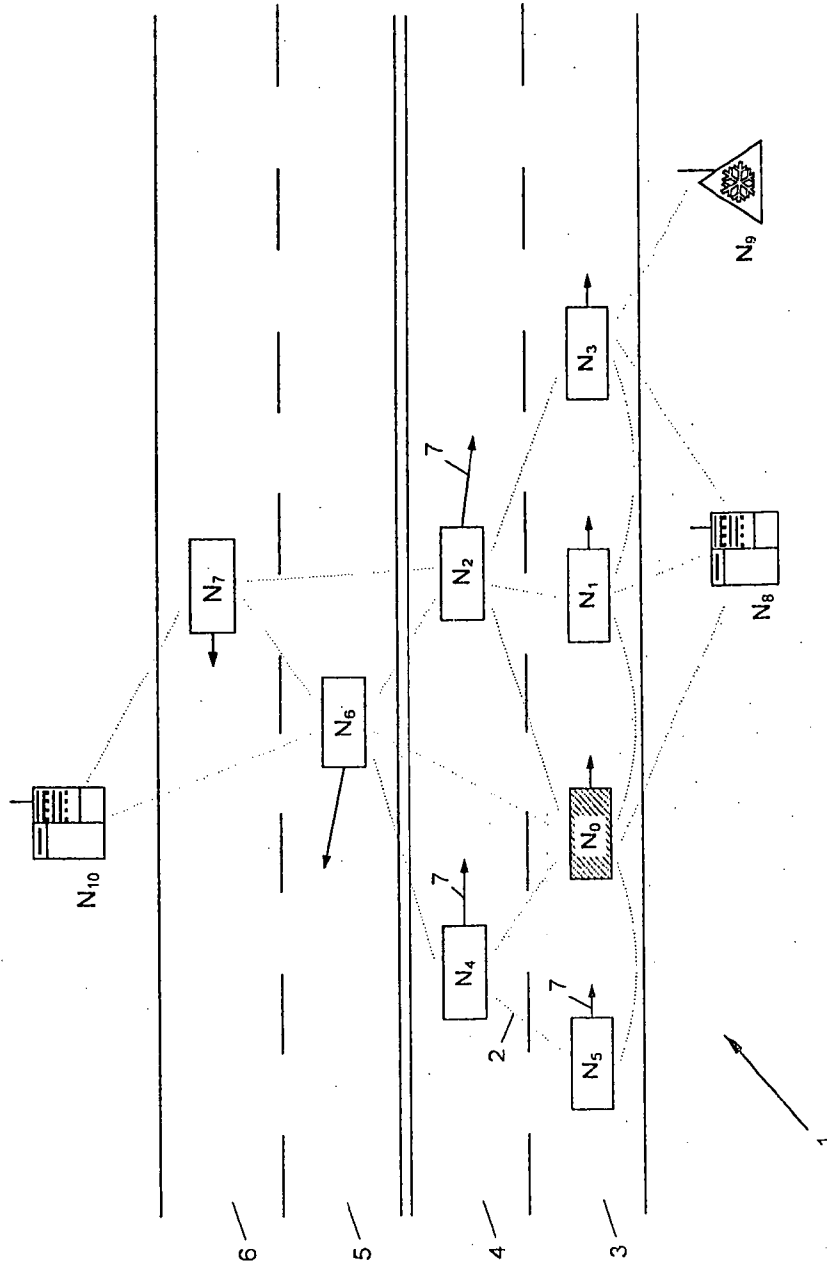


Fig. 1

**Network Node for an Ad-Hoc Network and Process for Providing Application Services
in an Ad-Hoc Network**

The present invention relates to a network node for an ad-hoc network having a plurality of network nodes of the same type, which provide one another with application services via wireless connections. The invention also relates to a process for providing application services in an ad-hoc network, the network nodes of which provide one another with application services via wireless connections.



Wireless ad-hoc networks, i.e. networks that are formed from a group of peers (network nodes) spontaneously connecting to one another and are generally highly dynamic because of the movement and changeover of network nodes, are a research field in its infancy that is being increasingly applied and widespread. The present invention relates in particular to the application of ad-hoc network technologies for networking vehicles in so-called vehicular ad-hoc networks (VANETs).

Numerous routing algorithms have already been proposed for VANETs to find the best possible route for data packets from one network node to another network node. However, the known routing algorithms for VANET network graph models are not suitable for the provision of satisfactory network-wide application service switching. The object of the invention is to provide such a means.

In a first aspect the invention provides a network node of the aforementioned type for this purpose that is distinguished in that it generates a list of all application services provided to it by other network nodes with associated quality classes and makes this list available to other network nodes as list of the application services provided by it with such classes, wherein said quality class is at least dependent on the number of consecutive network nodes, via which the application service is provided, and the quality class specified by the last of these network nodes.

In this way, in each network node a local application overview is generated in the form of the said list of all application services available to this network node with their respective service quality, which list is also referred to as "local available service table" (LAST). The LAST list of a network node is composed - recursively as it were - of the LAST lists of the adjacent

nodes receivable by this network node, which are in turn composed of the LAST lists of their adjacent network nodes, and so on. The LAST lists can therefore be generated locally and independently by each network node and still provide a complete overview of all application services currently available in the entire ad-hoc network without requiring a central distribution or survey mechanism or any specific routing algorithms.

The said quality class is preferably additionally dependent on the connection quality of the last wireless connection, via which the application service is provided, wherein it is in turn particularly preferred if the connection quality is dependent on the bandwidth, the latency and/or movement vectors of the wireless connection. As a result, highly dynamic and highly mobile network topographies can also be taken into consideration.

According to a preferred embodiment of the invention the network node additionally contains a list of booked application services and matches the LAST list with said booked application services and in the case of a match notifies an application in the network node. As a result, entry into specific service coverage regions can be detected and associated applications can be automatically launched, for example.

The list of provided application services preferably also contains an access authorisation class for each application service, e.g. depending on associated cost or user group.

The network node according to the invention is particularly suitable for vehicular ad-hoc networks (VANETs), in which case it is an onboard unit (OBU), such as currently used e.g. for wireless toll systems according to the DSRC, WAVE or GPS/GSM standard.

In a second aspect the invention provides a process for providing application services in an ad-hoc network, the network nodes of which provide one another with application services via wireless connections, characterised by the steps
in one network node: creating a list of all application services provided to this network node by other network nodes with associated quality classes and making available this list for other network nodes as list of the application services provided by it with such quality classes, wherein said quality class is at least dependent on the number of consecutive network nodes, via which the application service is provided, and the quality class specified by the last of these network nodes.

Reference is made to the above explanations concerning the network node for further features and advantages of the process according to the invention.

The invention shall be explained in further detail below on the basis of an exemplary embodiment with reference to the attached drawings, wherein:

- Figure 1 shows an overview of a vehicular ad-hoc network with network nodes according to the invention;
- Figure 2 shows a detail in sectional view of the network of Figure 1;
- Figure 3 shows the structure of a LAST list in a network node; and
- Figure 4 is a schematic diagram of quality classes and their variation from network node to network node.

Figure 1 shows a snapshot of an ad-hoc network 1 comprising a plurality (here eleven) of network nodes N_0, N_1, \dots, N_{10} , which can communicate with one another via wireless connections 2. The wireless connections 2 generally have a limited range, and therefore one network node N_i only communicates with closely adjacent network nodes, i.e. via a single wireless connection 2 ("single hop"), whereas it communicates indirectly with other network nodes, i.e. via multiple consecutive wireless connections 2 or intermediate network nodes N_j ("multi-hop").

The wireless connections 2 can be of any type known in the art, e.g. DSRC, mobile radio or WLAN connections, in particular according to the WAVE standard (wireless access in a vehicle environment).

In the shown example, some of the network nodes N_i are onboard units (OBUs) that are carried by vehicles (see network nodes N_0-N_7), others are e.g. stationary network nodes such as an exemplary wireless toll station N_8 (toll beacon), an ice warning system N_9 or a wireless internet access point N_{10} . Any other desired types of network nodes N_i are conceivable, e.g.

wireless vending machines for entry tickets, parking tickets, city toll tickets or the like, communication terminals, traffic monitoring systems, mobile access points etc.

The in-vehicle network nodes N_0-N_7 in the shown example are moving on a four-lane motorway with two lanes 3, 4 running in one direction of travel and two lanes 5, 6 running in the other direction of travel. The arrows 7 indicate the current speed vector (speed, direction) of the mobile OBU network nodes N_0-N_7 .

The network nodes N_i provide one another with application services S_n via the wireless connections 2, i.e. both those directly originating in the respective provider network node, see e.g. the ice warning services S_1 of network node N_0 , and those that are merely passed on from a network node, as is primarily the case with OBU network nodes N_0-N_7 . In the same way, the application services S_n provided to a network node N_i can be used by this network node itself, e.g. by a software application running on the network node N_i , and can also be passed from this network node onto other network nodes again.

For said purposes, each network node N_i generates a list $LAST_i$ of all application services S_n provided to it by other receivable network nodes N_j (via wireless connections 2). The list $LAST_i$ shall now be explained in more detail with reference to Figures 2 - 4.

Figure 2 shows a simplified sectional view onto the ad-hoc network of Figure 1, viewed from the network node N_0 , which generates its $LAST$ list $LAST_0$ on the basis of the direct wireless connections 2 with its directly adjacent network nodes N_1, N_2, N_4, N_5, N_6 and N_8 . The latter nodes themselves have respective lists $LAST_i$ - generated from their local overview. In general terms, the lists $LAST_i$ are respectively generated "recursively" as it were from the lists of the receivable network nodes N_j .

For each application service S_n available for the network node N_i , each list $LAST_i$ contains a quality class QEC_{in} (quality estimate class) of the application service S_n . The quality class QEC_{in} is composed of the number of consecutive wireless connections 2 or network nodes N_j , via which the application service S_n is provided ("hops"), and the quality class QEC_{jn} specified by the last network node N_j in its list $LAST_j$; and is also preferably composed of the connection quality Q_{ij} of the last wireless connection 2, via which the application service S_n is provided to the network node N_i by the last network node N_j .

An example: the "ice warning" service, which is provided by the network node N_9 in its list $LAST_9$ as service S_1 with, for example, the best quality class QEC_{91} of "0" (representative of "zero hop", high availability and high bandwidth), is classified in the list $LAST_3$ of the next network node N_3 - after transmission via the wireless connection 2 with the connection quality Q_{39} - in the lower quality class QEC_{31} of "1", which e.g. stands for "single hop", high availability and a slightly reduced bandwidth, as a result of e.g. a connection quality Q_{39} of the wireless connection 2 of 90%.

The next network node N_1 on the propagation route towards the network node N_0 in turn builds its list $LAST_1$ on the $LAST$ lists of the network nodes in the vicinity, including the $LAST_3$ list of the network node N_3 , and once again calculates a quality class QEC_{11} for the ice warning service S_1 with the consideration that there are now already two hops present, and with consideration of the connection quality Q_{13} from network node N_3 to network node N_1 . In the same way, the network node N_0 in turn generates its $LAST_0$ list from the data of the $LAST_1$ list, amongst other things, by incrementing the number of hops by 1, with consideration of the connection quality Q_{01} and new classification of the service quality of the ice warning service S_1 in the quality class QEC_{01} of e.g. "3", representative of "triple hop", high availability and a bandwidth of e.g. 60%.

If in one network node N_i , e.g. network node N_0 , one and the same service, e.g. the ice warning service S_1 of network node N_9 , can be switched via different paths in the ad-hoc network 1, e.g. here via $N_9-N_3-N_2-N_0$, $N_9-N_3-N_1-N_0$, $N_9-N_3-N_8-N_0$ etc., then these different possibilities can be included as different service entries S_n in the list $LAST_i$, respectively with the corresponding quality class QEC_{in} , or only the entry with the best quality class QEC_{in} can be respectively stored in the list, which leads to an implicit best routing.

The connection quality Q_{ij} of a wire [sic] connection 2 can be dependent on a plurality of parameters, which a network node can preferably determine itself, e.g. the bandwidth and/or the latency of the wireless connection 2 and/or the latency of the application service S_n , if this is a processing service, for example. The connection quality Q_{ij} can preferably also take the movement vectors 7 of the partners of the respective wireless connection 2 into consideration: thus it can be taken into consideration, for example, that network nodes that are expected to only encounter one another briefly on the basis of their vectors 7, see e.g. the

network node N_6 approaching network node N_4 or the network node N_4 overtaking network node N_5 in Figure 1, result in a lower quality class for application services provided in that regard than other less dynamic wireless connections 2, e.g. between two network nodes moving approximately equally quickly in the same direction.

The following Table 1 shows some examples of quality classes QEC, which can be defined on the basis of the number, bandwidth, latency and/or direction vectors of the wireless connections or participating network nodes and/or the availability class of the service provider:

QEC = 1	Single hop, probable availability 100%
QEC = 2	Single hop, probable availability 90% (e.g. 100 kbit/s for 30 seconds)
QEC = 3	Triple hop, probable availability 80%
QEC = 4	Double hop, probable availability 60%

Table 1

As shown in Figure 4, the quality class QEC_{in} or QEC_{jn} of an application service S_n in the list $LAST_i$ of a network node N_i or N_j can also be seen as a restricted region 8 or 8' in a multidimensional space 9, which the individual parameters such as hops, bandwidth, availability etc. cover. Variations in one or more of these parameters, as occur e.g. when an application service S_n is passed on from one network node N_j to another network node N_i , can thus lead to classification in the list $LAST_i$ of the next network node N_i in a different region 8' from previously (8) and thus in a different quality class QEC_{in} from previously (QEC_{jn}).

In addition to the quality class QEC, the list $LAST_i$ can also contain a service class SC for each application service S_n , see Figure 3 and the following Table 2:

SID = 0	Safety alert service vehicle
SID = 1	Safety alert service infrastructure
SID = 2	Sensor service vehicle
SID = 3	Sensor service infrastructure
SID = 4	Service point
SID = 5	Infrastructure charging point service
SID = 6	Infrastructure tolling info point service

Table 2

The service class SC can be used, for example, by network node N_i or its applications in order to “book” application services S_n of a specific service class SC. A software application on a network node N_i can thus be notified automatically, for example, if an application service S_n of a specific service class SC is available. Specific application services S_n can, of course, also be booked directly in a network node N_i on the basis of their name (service name, SN).

The list $LAST_i$ can also contain an access authorisation class AC for each application service S_n , see Figure 3 and the following Table 3:

AC = 1	Free access for all
AC = 2	Safety subscriber, certificate required, flat fee
AC = 3	Convenience subscriber, certificate required
AC = 4	Tolling service provider, certificate required
AC = 5	Roadside warning service provider, no certificate

Table 3

The access class AC can be applied by network nodes N_i or their software applications to match the access authorisation to a specific application service.

A network-wide certificate system can be implemented for utilisation of the application services S_n made available to a network node N_i . For this purpose, the network nodes N_i - or the applications running on them - can identify themselves to the application services S_n utilised by means of appropriate public/private key certificates, for example, as is known in the art. It is also possible in this case to use time-restricted certificates so that application

service requests, which are transmitted to application service providers from network nodes with time-restricted certificates, can be authenticated and implemented in a time-controlled and/or time-checked manner.

The invention is not restricted to the represented embodiments, but covers all variants and modifications falling within the framework of the attached claims.

**Claims:**

1. Network node for an ad-hoc network having a plurality of network nodes of the same type, which provide one another with application services via wireless connections, characterised in that the network node (N_i) generates a list ($LAST_i$) of all application services (S_n) provided to it by other network nodes (N_j) with associated quality classes (QEC_{in}) and makes this list ($LAST_i$) available to other network nodes (N_i) as list of the application services (S_n) provided by it with such quality classes (QEC_{in}), wherein said quality class (QEC_{in}) is at least dependent on the number of consecutive network nodes, via which the application service (S_n) is provided, and the quality class (QEC_{jn}) specified by the last of these network nodes.
2. Network node according to claim 1, characterised in that the quality class (QEC_{in}) is additionally dependent on the connection quality (Q_{ij}) of the last wireless connection, via which the application service (S_n) is provided.
3. Network node according to claim 2, characterised in that the connection quality (Q_{ij}) is dependent on the bandwidth and/or the latency of the wireless connection.
4. Network node according to claim 2 or 3, characterised in that the connection quality (Q_{ij}) is dependent on movement vectors of the wireless connection.
5. Network node according to one of claims 1 to 4, characterised in that it additionally contains a list of booked application services and matches the list ($LAST_i$) of provided application services (S_n) with said booked application services and in the case of a match notifies an application in the network node (N_i).
6. Network node according to one of claims 1 to 5, characterised in that the list ($LAST_i$) of provided application services (S_n) also contains an access authorisation class (AC) for each application service (S_n).
7. Network node according to one of claims 1 to 6 for a vehicular ad-hoc network, characterised in that it is an onboard unit (N_0-N_7).

8. Process for providing application services in an ad-hoc network (1), the network nodes (N_i) of which provide one another with application services (S_n) via wireless connections, characterised by the steps
in one network node (N_i): creating a list ($LAST_i$) of all application services (S_n) provided to this network node (N_i) by other network nodes (N_i) with associated quality classes (QEC_{in}) and making available this list ($LAST_i$) for other network nodes (N_i) as list of the application services (S_n) provided by it with such quality classes (QEC_{in}),
wherein said quality class (QEC_{in}) is at least dependent on the number of consecutive network nodes, via which the application service (S_n) is provided, and the quality class (QEC_{jn}) specified by the last of these network nodes.
9. Process according to claim 8, characterised in that the quality class (QEC_{in}) is additionally dependent on the connection quality (Q_{ij}) of the last wireless connection, via which the application service (S_n) is provided.
10. Process according to claim 9, characterised in that the connection quality (Q_{ij}) is dependent on the bandwidth, the latency and/or movement vectors of the wireless connection.
11. Network node according to claim 1, substantially as herein described with reference to and/or as illustrated by any of the accompanying figures.
12. Process according to claim 8, substantially as herein described with reference to and/or as illustrated by any of the accompanying figures.

Dated this 13th day of January 2011



Adams & Adams
Applicants Patent Attorneys

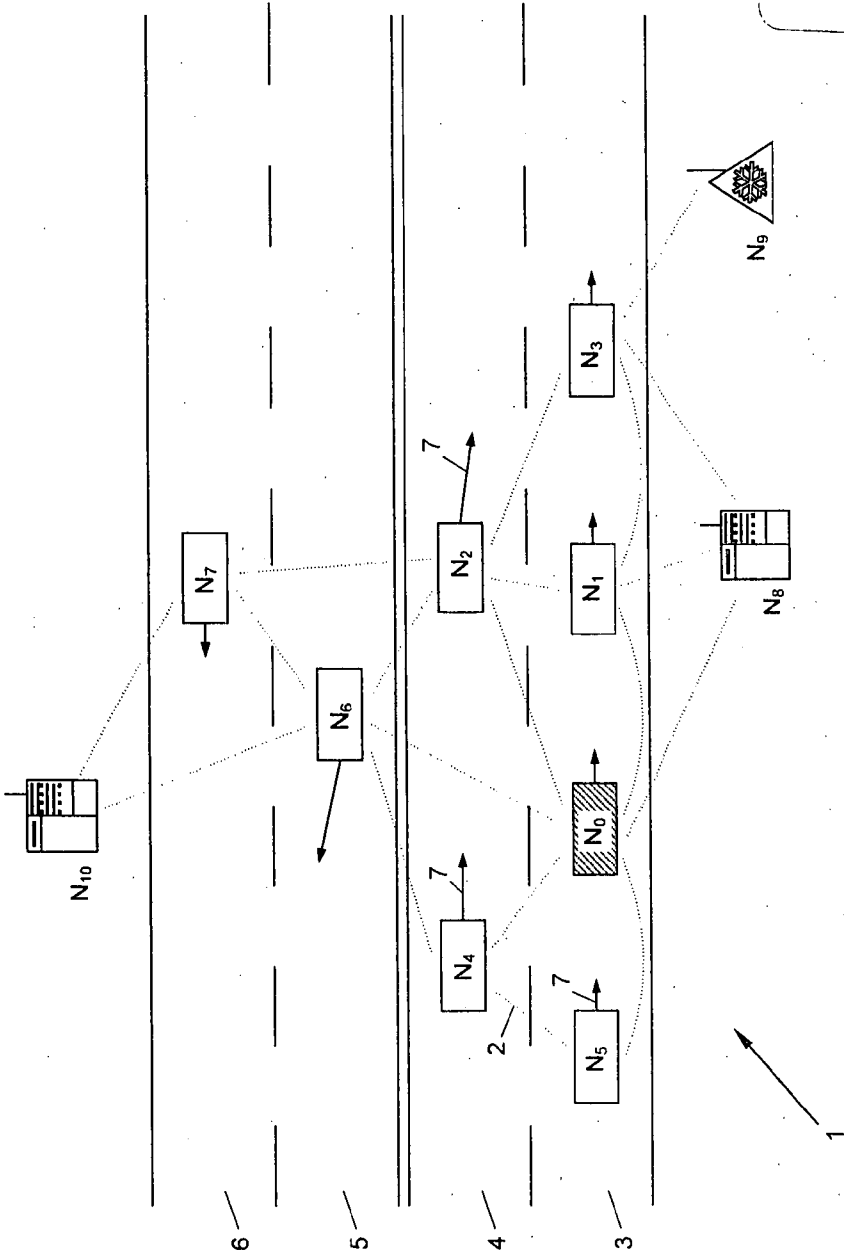
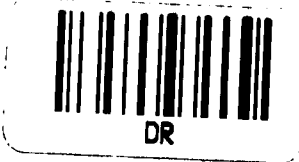


Fig. 1

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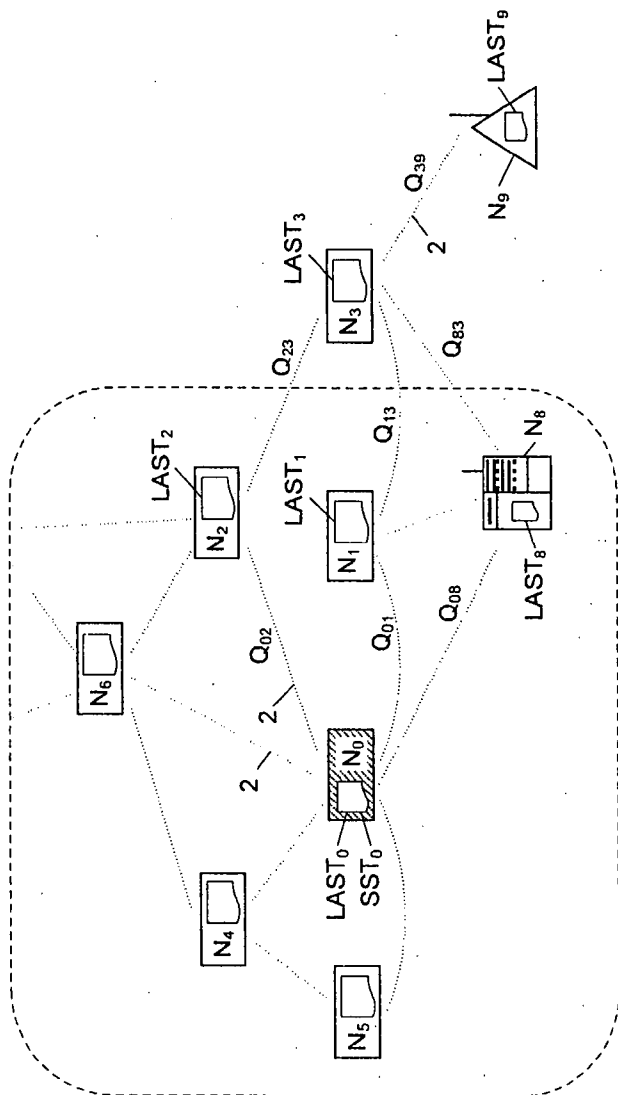


Fig. 2

Service Name (SN)	Service Class (SC)	Quality Estimate Class (QEC)	Access Class (AC)
S ₀ "Roadwork Warning"	1	2	1
S ₁ "Icy Road"	1	3	2
⋮	⋮	⋮	⋮
"Parking House Reservation"	4	4	1
"Internet Access"	4	4	3
"Geisterfahrer"	0	1	1
S _n "Vehicle Brake"	0	3	1
⋮	⋮	⋮	⋮
"Tolling Station Charge Object"	5	4	4
"Parking House Availability"	4	3	1
"Invoicing Service"	5	2	5
⋮	⋮	⋮	⋮

LAST

Fig. 3

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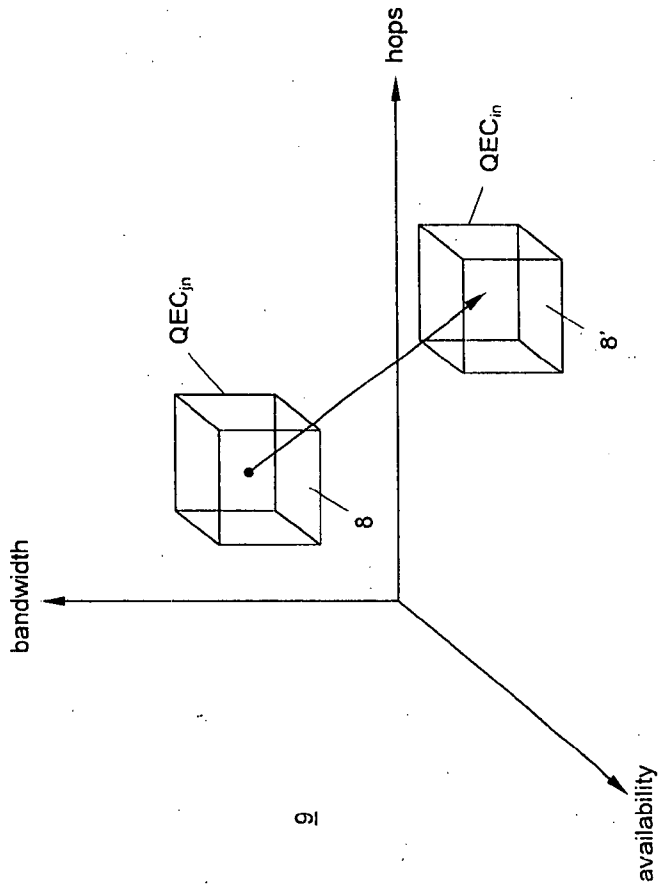


Fig. 4

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