Route Calculation Process of Infrared Beacon in Dynamic Route Guidance System

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ABSTRACT

In the Universal Traffic Management Systems (UTMS) now being studied and developed in Japan, the infrared beacon (referred to as IR beacon from now on) is used for realizing the Dynamic Route Guidance System (DRGS) in real world. In DRGS, the IR beacon receives an optional destination information a driver specified, and immediately sends back to the vehicle the dynamic route guidance information including the most suitable route to the required destination.

This paper describes methods of data calculation process incorporated with the IR beacon for realizing DRGS, and also evaluated results on the performance of IR beacons developed for an DRGS verification test scheduled to be carried out this fall.

PREFACE

UTMS project, as shown in Figure 1, is now studied and developed in Japan under an initiative of the National Police Agency (NPA). One of UTMS sub-systems, AMIS is a system that provides drivers with such information as traffic jam, accidents, road works etc. via IR beacons to car navigation units. It has played a major role in operating the Vehicle Information & Communication System (VICS), which started its practical service since April 1996. As the information service to be expanded in the future, the dissemination of DRGS information is urgently required, because DRGS functions of traffic flow distribution could effectively facilitate in improving the traffic environment, as well as these DRGS information are considered as value added for drivers.

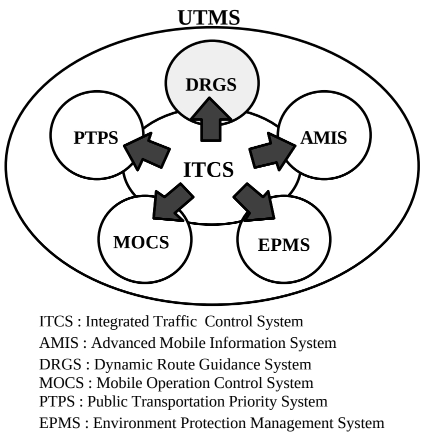


Figure 1 UTMS system configuration

OUTLINE OF DRGS AND ITS PROBLEM

Description of DRGS

The overview of DRGS currently studied in UTMS project is shown in Figure 2. The most distinguished feature of DRGS is that " the system receives the destination data from an in-vehicle unit while a vehicle is passing through an IR beacon's communication area, and then immediately calculates and provides route guidance information, including additional data, from the current location an IR beacon installed to the destination required by the driver". As other information added to the route guidance, we considered this time that the travel time and route length should be included.

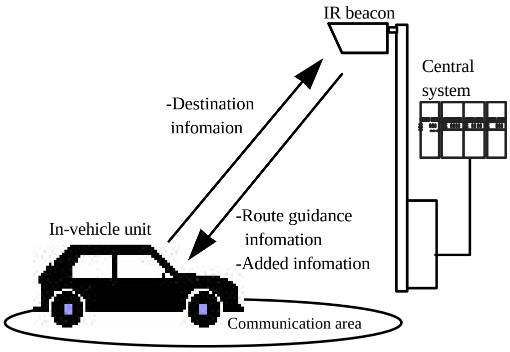


Figure 2 Overview of DRGS

In addition, following conditions have been required to satisfy in implementing the DRGS this time.

(1) The system should support any destination sites all over the country:

Mainly due to hardware restrictions with the IR beacon, it is impossible to support such wide areas including all destinations voluntarily specified by motorists. So, we have defined two types of area; one is the short-distance area and the other is the long-distance area. Within the short-distance area, you can provide a whole route toward the final destination. On the other hand, when a destination required by a driver belongs to a long-distance area, you can only provide a route within a short-distance area, which leads to a suitable connection link (expressway or arterial) toward the final destination site. The farther a long-distance area exists from the current point, the larger the area is defined by a form of semi-square, and which long-distance area the destination involved in is judged according to the up-link information. If a destination specified by a driver is involved in a long-distance area, the destination is converted into a link number in an appropriate short-distance area, which connects to the long-distance area. Based upon the statistics on the average trip length, etc., a short-distance area is now defined as a half circle with a radium of 20 kilometers centered around a IR beacon's location, but the size of the area is to be widened to 30 kilometers in the future.

(2) The system should maintain a real-time feature:

Dynamic information is to be updated every five minutes with taking considerations to the real-time basis of the system.

(3) The system should provide information other than DRGS:

These information such as traffic jams, accidents or road works already provided by AMIS are to be provided at the same time DRGS information is disseminated.

Description of IR Beacon

As shown in Figure 3, the IR beacon allows to make two-way communications via infrared rays with the in-vehicle unit using LED emitting and photo-diode receiving sections. The information transmitted from an IR beacon to an in-vehicle unit is called down-link, and from an in-vehicle unit to an IR beacon, called up-link.

The outline of this road-vehicle communications is given below.

(1) Communication performance:

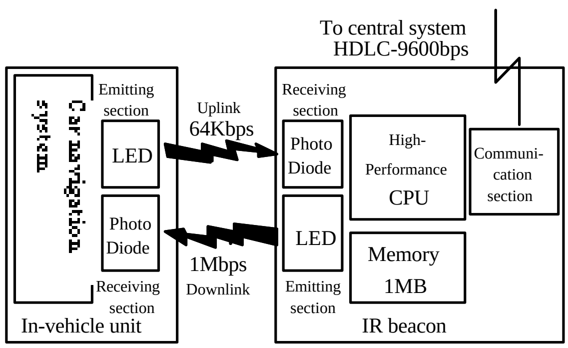


Figure 3 Hardware configuration of IR beacon

Communication speed is 64 kilobits per second for up-link; 1,024 kilobits per second for down-link. For down-link information, data can be transmitted up to 80 frames, i.e. 10 kilobytes in total (128 bytes per one frame) to a vehicle which is passing through at a speed of 70 kilometers per hour or less.

(2) Size of communication area:

3.7 meters approximately. Therefore, the duration a vehicle running at a speed of 70 kilometers per hour passes through the communication area is about 190 milliseconds. In order to avoid communication errors, a set of the same down-link information is transmitted twice.

(3) Timing chart:

A timing chart including traffic congestion information is shown in Figure 4.

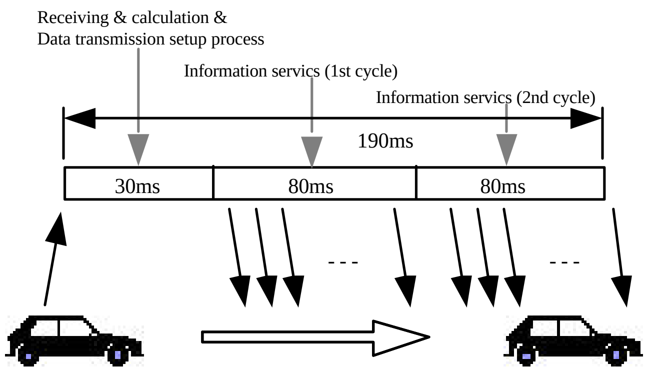


Figure 4 Timing chart of road vehicle communications

How to Specify Road Position

UTMS has common definitions on "mesh" and "link" in order to unify the road location information for both in-vehicle units and infrastructures.

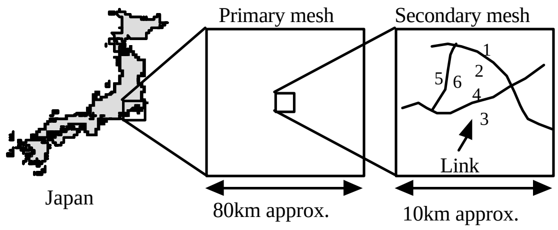


Figure 5 "mesh"&"link"

(1) Mesh:

The whole land map of Japan is divided into many semi-square forms under considerations to latitude and longitude. Each squared form is called "mesh". There are two kinds of mesh, primary and secondary, as shown in Figure 5. Mainly used in UTMS are secondary meshes. The whole land of Japan consists of 4,400 secondary meshes, and each mesh has a unique number.

(2) Link:

Each direction of well-known roads in secondary meshes have been divided into sections by using intersections or important road points. This divided one has been defined as a link. Each link in a secondary mesh is assigned by a unique number. Average numbers of links in typical urban areas are as many as some 400 links per one secondary mesh. The central part of Tokyo with the highest density of road networks has a total of some 6,000 links per a 20-kilometer half-circle area.

Due to these definitions, any road networks all over Japan can be represented by a unique secondary mesh number plus link number, which is utilized by UTMS.

Communication Data between In-vehicle Unit and IR Beacon

In Japan, cooperative efforts in promoting UTMS project have continued, in which the government engages in constructing infrastructures and the industry shares developing in-vehicle units, so AMIS was realized through efforts of advancing the existing car navigation system. On the other hand, such car navigation system has already adopted the digital map database and realized the capability of route guidance function, with which a distance between intersections is calculated as a link cost. This existing function can manage a route information from the current vehicle location to a destination on the map. It can also perform a voice guidance or simplified map display during traveling, if necessary. In DRGS, therefore, we are required to provide the route guidance information from the current vehicle position to a destination, as precisely as possible.

Contents of up-link and down-link information are described below.

(1) Up-link information:

-Vehicle type; passenger cars or large-sized vehicles.

-Road to be used; highways including toll roads or ordinary roads only.

-Destination; specified with secondary mesh and link numbers. Following specification methods are available.

a) To specify a link; allows to request a route that is the fastest way to the specified link.

b) To specify a relative position in a link; allows to specify a relative position with the number of 0 to 10 in addition to secondary mesh and link numbers. A relative position in the link means a destination which represented by a unit of 10-percent of the link length from the beginning of the link. A link that is the fastest way to the specified destination can be requested, taking into account forward or backward order.

(2) Down-link information:

-Route information; provides a route from the current position to a destination. The route is a queue of links represented by the secondary mesh number plus link number.

-Travel time information; provides the travel time for the route.

-Distance information; provides the distance of the route.

Technical Problem

Based upon what we discussed above, technical problems for realizing DRGS can be stated as follows.

(1) Process performance:

After receiving the up-link information, the route calculation process and transmission data setup process should be performed within 20 milliseconds. According to the results from AMIS operations, the time, during which an IR beacon receives up-link information from a vehicle entered into a communication area, is less than 5 milliseconds. In addition, the time, during which an IR beacon sends down-link after completing both route calculation process and transmission data setup process, is less than 2 milliseconds. Considering to a tolerance period of 3 milliseconds, we have a target that these two processes should be completed within 20 milliseconds.

(2) Amounts of memory used:

The data corresponding to any optional destinations specified by drivers should be made together compactly in order to maintain them in a IR beacon. A total amount of memory allowed to be used both by DRGS and AMIS should be limited less than 1 megabyte. As the existing AMIS already uses 256 kilobytes of memory, DRGS programs are estimated to use 128 kilobytes of memory including work areas. Further, the IR beacon should maintain a dynamic data in double buffering manner allowing to communicate with an in-vehicle unit at the same time when the beacon is receiving the dynamic data from the central system. So, a total amount of memory allowed to be used by DRGS dynamic data and constants should be limited less than 640 kilobytes.

(3) The size of dynamic data:

With considerations to the real-time feature of DRGS, the dynamic data communications with the central system, which include AMIS data, should be completed within 120 seconds as a target. AMIS receives a maximum 20 kilobytes of dynamic data from the central system. The communication speed between the central system and IR beacon is 9,600 bits per second. And the transmission efficiency is estimated as some 40 percents or more according to the AMIS performance. So, an amount of dynamic data used by DRGS should be limited less than 36 kilobytes.

APPROACH

System Configuration

For realization of DRGS, system functions are assigned to each system component as shown in Figure 6.

(1) Central system

-Calculation of link cost:

A link cost based upon the travel-time is calculated. Used here include traffic flow data acquired from ultrasonic type of detectors, traffic accident data, road work information, and an average duration of time vehicles travel the link, which obtained from up-link, etc.

-Search for the shortest route:

The shortest route and its travel-time from a link where an IR beacon is installed to all links within the information service area are calculated by using the Dijkestra method, etc.

-Creation of route tree:

The shortest route calculated above is converted into a route tree described in the next section.

(2) IR beacon

-Calculation of the shortest route and its route length from a route tree, and extraction of its travel-time:

A queue of route links from the current location to a destination is calculated by using a route tree received every five minutes from the central system and road network data maintained by the IR beacon itself. At the time of this calculation, the additional information concerning the route such as the route length and route travel-time are also generated by sequentially adding each link length data and link travel-time maintained by IR beacons.

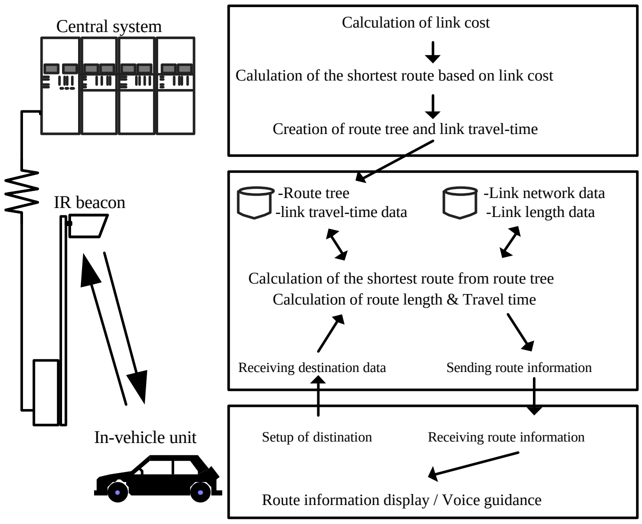


Figure 6 Function assignment for DRGS

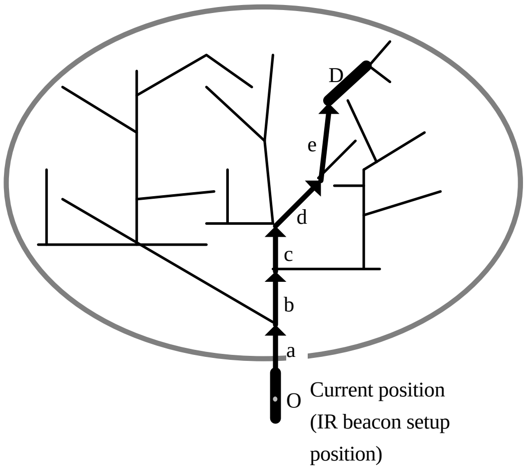


Figure 7 An example of a route tree

Route Tree

Figure 7 shows an example of route tree. A route tree employs the characteristics that "regarding all destination links, the upstream link connected to the shortest route which reaches a destination link is only one in every case." Consequently, it is possible that the shortest route information for all links is converted into compact data.

Figure 7 gives an example of a route from "O" (current position) to "D" (destination link). The Calculation procedure for the example is outlined below.

-Step 1:

Based upon a route tree data, the link "e" to be connected with the upstream side of destination link "D" is acquired.

-Step 2:

Based upon a route tree data, the link "d" to be connected with the upstream side of link "e" is acquired. When this "link reverse extraction process" is repeated until reaching the current position "O", such link queue as "D-e-d-c-b-a-O" is obtained.

-Step 3:

When the link queue acquired in the previous step is aligned in reverse order, the link queue "O-a-b-c-d-e-D", the shortest route from the current position "O" to the destination link "D" is obtained.

In some central parts of Tokyo, it is necessary to repeat around 40 to 60 times of such "link reverse extraction process" for reaching the final destination within a radius of 20 kilometers. It is also necessary for the IR beacon to do the process along with other processes such as accumulating calculation of the route length and the data transmission setup process, in which down-link information be converted into proper form of disseminated data. So, one link reverse extraction process must be done in 0.3 milliseconds. As a theoretical simulation proved that it was possible, so we decided that the above performance could be satisfied.

Contents of Data

Based upon what we have discussed in the previous section, we studied on constants and dynamic data, with considerations to the IR beacon's performance, memory capacity, and communications capacity with the central system. The outline of the studies are as follows:

-Link retrieval table:

Regarding the constants and dynamic data to be described below, the same numbers of records as those of links are generated with a sequential order of secondary mesh and link numbers. We have prepared a retrieval table for speedily searching for links when the up-link is received. The size of the table is 20 kilobytes.

-Route calculation:

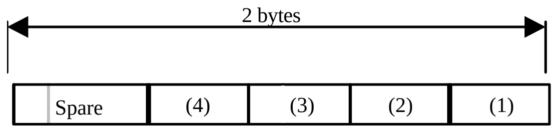
Dynamic data for a route tree has been aligned as shown in Figure 8, and an IR beacon maintains the network data just like a format shown in Figure 9. A general procedure of the process is that, after acquiring 1-5 (one to five) from the corresponding field in Figure 8, then making judgment on which upstream link address (#1 to #5) to be seen, and finally the data is jumped to the address which being indicated by the pointer.

-Specifying a relative position within a link:

For this procedure, we have used the dynamic data in Figure 10 and the constant in Figure 11. A relative position (0 to 10) within a link received from an in-vehicle unit is compared with the value in corresponding field of Figure 10. If the relative value is larger than the dynamic data, the reverse direction is judged as a faster route. Then, after acquiring the reverse direction link from data in figure 11, the route is calculated using

-Distant destination:

If a destination specified belongs to a long-distance area, the destination is converted into an appropriate link within a short-distance area and the route to the destination is provided. Since these kinds of long-distance area are estimated to be existing as many as some 8,000 per one IR beacon, the size of this conversion table is as large as some 40 kilobytes.



(1):Upstream link pointer(1to5) for passenger cars & all roads
(2):Upstream link pointer(1to5) for passenger cars & ordinary roads
(3):Upstream link pointer(1to5) for laege-sized vehicles & all roads
(4):Upstream link pointer(1to5) for large-sized vehicles & ordinary roads

Figre 8 Dynamic data (route tree information)

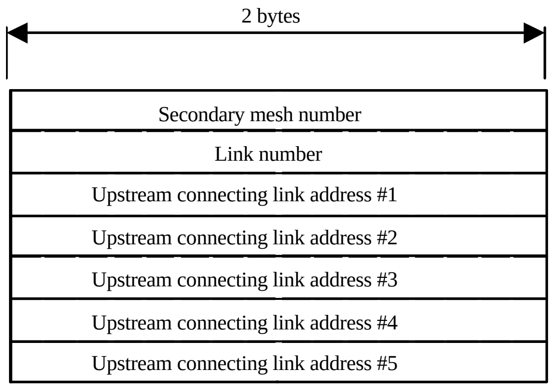
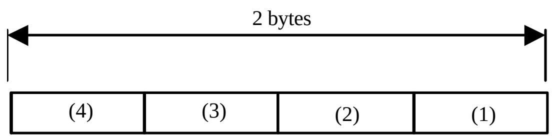


Figure 9 IR beacon constants (network data)



(1):Passenger cars & all roads
(2):Passenger cars & ordinary roads
(3):Large-sized vehicles & all roads
(4):Large-sized vehicles & ordinary roads

Values of 1 to 10 are taken for above

Figure 10 Dynamic data (judgment of relative position in link)

-Additional information for route:

The additional information for a route has been treated by the constants involved in Figures 12 and 13. Along with the link reverse extraction process, the route length and travel-time are calculated by sequentially adding the link length and link travel-time included in Figure 12 and 13, respectively.

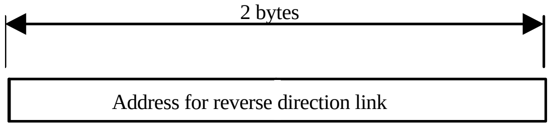


Figure 11 IR beacon constants (reverse direction link)

Beforehand Estimated Performance of IR Beacon

Following the methods mentioned above, we have estimated the performance of an IR beacon in advance. This estimation have been done under a condition that the maximum numbers of link for a IR beacon are as many as 6,000 within a 20-kilometer area.

In an experiment to be conducted this time, we are going to neglect using the method, "specifying relative position within a link", so that any dynamic data shown in Figure 10 has not been created.

(1) Process performance:

The route calculation process and transmission data setup process can be done within 20 milliseconds.

(2) The amount of memory to be used:

A total memory to be used for an IR beacon is 218 kilobytes, and in a case the dynamic data for specifying the relative position is omitted, it decreases to 195 kilobytes.

(3) The size of dynamic data:

A total size of dynamic data is 29.3 kilobytes, and 17.6 kilobytes without the relative position data.

These performance data mentioned above will meet our first target.

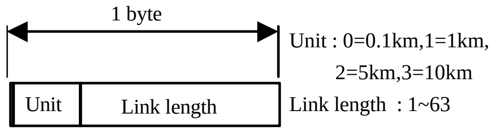


Figure 12 IR beacon constants (link length data)

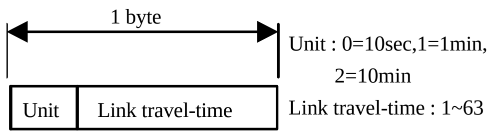


Figure 13 Dynamic data (link travel-time data)

PERFORMANCE EVALUATION ON IR BEACON

As a field experiment for verifying DRGS functions is scheduled to be carried out in Tokyo this October, the installation of a system for the experiment, which uses the methods mentioned previously, is now promoting. Originally, the experiment was scheduled to be conducted in July, but it was postponed.

We have conducted an evaluation on performance of the IR beacon, which is actually to be used at the coming field test. Major preconditions applied to the evaluation are as follows.

-This evaluation has been carried out over the IR beacon itself, so it is not connected with a central system. In the practical operation test on DRGS, it will become necessary for the IR beacon to conduct communications processes with the central system in parallel to all processes mentioned above. However, AMIS achievement results show us that the work load of CPU in an IR beacon is not increased so much, or almost negligible if the communication process with the central system is added.

-Currently we do not have any in-vehicle unit that is capable of sending or receiving the up-link information for DRGS. Therefore, we have directly given the destination data to the CPU memory area, in which up-link data is maintained, and have measured the duration of time until generating down-link information is completed.

-The constants set up in the IR beacon for this evaluation are the same data that is scheduled to be used with the coming field experiment. The dynamic data used this time is also the real data created based upon the traffic information acquired from the traffic control system.

Performance of the IR beacon has been evaluated based upon such these preconditions as mentioned above, and the results are presented as follows.

(1) Process performance:

An average time per one link reverse extraction process was around 0.1 milliseconds. We selected a link located at farthest position within a short-distance area, and measured its process time. As a result, a total number of links was counted as many as 66 between the position of IR beacon and the destination. Regarding the process time, it required 10 milliseconds from receiving the up-link till finishing the down-link compile including the link retrieval process using the retrieval table.

(2) The amount of memory:

A total amount of memory used by this evaluation was 275 kilobytes.

(3) The size of dynamic data:

A total size used for dynamic data in this evaluation was 22 kilobytes.

Although both the total amount of memory used and size of dynamic data are enlarged a little more than those estimated beforehand, it can be said that there is no problem in practical use of DRGS. Because, reasons for these increased memories or dynamic data have been clarified as shown below.

- In addition to these information described in above sections, more information such as various kinds of abnormal messages and other data for dealing with troubles have been attached to the IR beacon used in this evaluation.
- Various kinds of control information, which will be necessary for the practical DRGS operation, have also been added to the IR beacon.
- A total number of links accommodated in the IR beacon has become as many as 6,338, which is bigger than 6,000 links expected in a beforehand estimation.

TECHNICAL ISSUES TO BE SOLVED IN FUTURE

(1) We have evaluated this time only the performance of the isolated IR beacon. Especially regarding the performance of the route calculation process, it will be necessary for us to evaluate an actual performance of IR beacons, which are under communications with the central system and in-vehicle unit.

(2) Although every long-distance area is modeled by a similar form of semi-square in this experimental system, it will become necessary to coordinate each form of areas conforming to their actual geographical features.

(3) A long-distance area is connected with each short-distance area by only one link in the current system. However, for a long-distance area relatively located near the current position, an optimum route to be provided may be far different from a route, which calculated as the shortest travel-time route. So, it will be necessary for us to establish some numbers of links in a short-distance area corresponding to one long-distance area, and allow to select dynamically the shortest travel-time route to be provided.

(4) Other than the basic information for DRGS described in this paper, the down-link service information currently being studied for UTMS includes the following:

- Road point names on the way of a route provided by character codes
- Major traffic information on the way to a destination provided by character codes or sentence pattern codes
- Information on right- and left-turning lanes of the nearest intersection.
- Optional routes (around three routes) service

To realize such functions mentioned above, CPU performance, memory capacity and communication speed of IR beacon must be improved. Further, the improvement of software, or processing methods are required.

REFERENCES

[1] Pamphlet of VICS, Vehicle Information and Communication System Center
[2] Pamphlet of UTMS, Universal Traffic Management Society of Japan