IMERP

Intelligent and Modular Electronic Road Pricing System

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I. Technical field

This systems relates to Electronic Road pricing Systems.

II. Background

Modern cities are and will be more and more faced to car traffic problems. This is particularly true for specific parts of cities such as financial or business districts. In order to rule, control, monitor or even limit usage of road and/or cars, in special districts or on a large territory, Modern states and cities are thinking of installing electronic and computerized systems known as Electronic Road pricing Systems (ERP).

ERP can on one hand control and track cars and vehicles (motorcar, trucks, ...) and on the other hand charge owners of the vehicle for the usage of areas or roads. The usage of area and/or roads can be charged either paying an entrance ticket or following the kilometers ran (these two techniques being not exclusive of each other).

Many technologies can be used in ERP such as, code and signal recognition, real time tracking, short wave, infrared or hertzian communications, smart card, computers, ...

III. Examples of two possible systems

In order to explain by contrast the advantages of the system proposed herein, we are going to shortly describe two other possible ERP systems.

III.1. Example 1 : The Big Brother System

The Big Brother (B.B.) system can be divided in three part :

1. Car Tag : Each car is given a specific and unique tag which will allow its identification by a tracking system.

2. Tracking system : The tracking system consist in a series of sensor sensible to the passing over of a car equipped with a car tag. This tracking system can either be optical or electronic depending on the nature of the car tag. The car being identified by each sensor, it is therefore possible to track the vehicle, i.e. not only to know its position bit also the number of kilometers it is running.

3. Communication and computer system : The information coming from the tracking system can be transmitted, using a network, to a computer system which will enter the information in the account of the owner in order to invoice him regularly.

This very centralized system has a lot of drawbacks :

A - Technical :

A.1 The system is a real time system. This means that tracking of cars is done on line, as well as the communication to the central computers. It therefore needs to be in function 24 hours a day.

A.2 The tracking system must be able to track many cars at the same time, on the same road, on different lanes of the road. This is a big technical challenge and therefore it is a real critical issue of such a system.

B - Operational :

B.1. As it is, the system is unable to track cheat cars. To do so, it is necessary to associate it with another system (functionally very different) such as a photographic system to keep track (but in another format) of the cheat car, and this as far as it can recognize a cheat car as such (which is also a technical challenge).

B.2. B.B. being a real time system, the number of transaction to perform simultaneously represent a real bottleneck and is a critical and weak point of the operations.

B.3. B.B. is difficult to make evolve. The installation of the system on a new area or road will require a lot of work.

C - Moral :

C.1. The system being able to know the location and date of each vehicle, it represents a potential danger for privacy.

D - Cost :

D.1. B.B. is expensive in its conception, for it involves and integrate different technologies and has to face many technological challenges

D.2. B.B. is expensive in its implementation (public work, networking, connection to the computer system, computer system itself) either in terms of investments or time.

D.3. B.B. is expensive at operation time for it is using this sophisticated infrastructure working during a long period of time if not around the clock.

D.4. B.B. is expensive in its maintenance, because of the very important infrastructure it represents, and because of the big number of components and their inter-relation.

D.5. The treatment of cheat car needed at least a manual operation, which will increase the global cost of the system.

III.2. Example 2 : The Smart Card Badge

Smart Card is a mastered technology which is started to be used in some ERP (parking payment for instance). The Smart Card Badge system might be working in the following ways:

1. Gates : Cars are entering a specific area passing through special *Gates* which are capable of sending a signal to the car. This signal is a code destinated to a special device in the car, which will identify the area in terms of entrance fees for instance. The gates might also be able to receive back from the car an acknowledgement signal. This signal can be kept in a local memory to be send in a differed way, to be processed if needed.

2. Smart Card Badge : The smart card badge is a dual system composed of a card reader and a smart card. The system is placed in the car by the owner.

   2.1. The smart card is mostly used to keep in memory prepaid tokens and additional informations. Those tokens will be consumed depending on the usage of road and area where the ERP is installed.

   2.2. The card reader is somehow intelligent in the sense that computer program might be coded in it. The Card reader is receiving from the gate the signal identifying the zone. At that moment many cases are possible :

- *The card is in the reader and is loaded with sufficient token* : In this case, the corresponding number of tokens is withdrawn from the card.
- *The Card is not in the reader or The card is in the reader and is loaded with insufficient token* : In this case, a signal is sent back to the gates to identify the car and to inform the gates of the amount which will have to be invoiced to the user.
- *There is no reader in the car* : In this case, The problem is to recognize such a car.

3. Automatic teller : Since the system is based on the prepaid concept, it is therefore necessary to create a network of automatic teller where token have to be bought.

As the previous one this system has some important drawbacks and unresolved problems :

A - Technical :

A.1 Even if this system si less centralized than the previous one, it is using a two way communicating intelligent gates system which embeds some intelligence.

A.2 Those gates must also be able to receive acknowledgement of the passing through of many cars at the same time, on the same road, on different lanes of the road. This is a big technical challenge and therefore it is a real critical issue of such a system.

B - Operational :

B.1. : As it is, the system has some difficulty to track cheat cars (car without a Smart Card Badges). To do so, it is necessary to associate it with another system (such as a photographic system to keep track (but in another format) of the cheat car, and this as far as it can recognize a cheat car as such (which is a technical challenge).

C - Cost :

C.1. This system needs the design and the implementation of an intelligent gate, able not only to send signals, but also to receive simultaneous acknowledgement of different car passing through it. It is therefore expensive in its conception, for it has to face many technological challenges.

C.2. The treatment of cheating cars needs at least a manual operation, which will increase the global cost of the system.

III.3 Conclusion

To summarize :

1. is technologically speaking a very risky system (if not unfeasible) and a very expensive too. In addition, privacy might be in peril with such a system.

2. More realistic, the Smart Card Badge system has to face (as the B.B.) the challenge of tracking simultaneously different car passing through on the same road, on different lanes, at the same time.

3. Both of them have no proper answer to the problem of cheat car. The problem being first to recognize them as such, and then (if done) to identify and invoice them. This might only be done through a parallel system based on different functionality, and which will break the homogeneity of the system.

IV. An intelligent & Modular E.R.P

IV. 1 Introduction

In order to obviate the technological and operational problems of the two previous systems, we have designed IMERP.

IMERP is a fully decentralized system, cheap to install, to operate, and to maintain. The coast effectiveness of IMERP is due to the fact that it is a simple solution based on existing and mastered technologies and using existing logistic infrastructures. In addition IMERP is highly extendible and reconfigurable. Last but not least, IMERP is a homogeneous system which not only allows efficient process of cheat cars but also dissuades cheating.

One of the main idea of IMERP is that most of the transaction and payment process is processed locally to the car.

IV.2. Description of the System components

IMERP can be divided in the following components :

1. Gates : In IMERP, gates are *dumb* in the sense that they are only sending signal. They don't have to acknowledge any reception from cars or keep track of transactions in a local memory. This simple signal is sent continuously during the period of operation. The signal is characterizing the area in which the car is entering. One particular gate might be able to send various type of signal. The gate is therefore a simple and stand alone device, which might possibly be mobile.

2. A smart card : This smart card is used :
    - To buy and store tokens from special selling point such as Automatic teller (ATM).
    - To be plugged in the *On Board Electronic System* (see point 3). In this context, the usage of the car within the road and area where IMERP is in operation will cause the consumption of the tokens.
    - To store information coming form the *On Board Electronic system* (see point 3) which might be used later on.
    - To store or transmit to the On board Electronic system others programs and/or data.

3. On Board Electronic System (OBES) : This sub-system is at the heart of IMERP. It is a fixed device personalized and attached to the car. It is composed of at least 4 parts, which are communicating :

   3.1. *A Smart Card Reader* : This part is communicating with the smart card, i.e. is capable to process Input/Output Operations on the smart Card (e.g. to debit the smart card with some tokens).

   3.2. *An intelligent electronic board* : This part of the sub-system is a computerized device, i.e. it contains :

   - Programs and Data (in Read Only Memory (ROM) for instance) which would be used during the usage of IMERP.
   - A Memory zone, where data will be stored or/and erased during the usage of the sub-system.
   - -Possibly a clock (time and/or date).

   3.3. *A reception system* : This wireless reception system is sensible to the signal sent by the gates. This reception will normal y trigger the debit of token.

   3.4. *A sending communication system* : This one direction system is a wireless communication system (e.g. shortwave, infrared, ...). This part of the system might be used on periodic date for a simple transaction with a identified computer system (or ordered list of computer systems). This periodic date (e.g. once in a month) is attached and specific to the car.

   Note 1 : OBES might be connected to the counter of the car, and therefore having access to kilometers of distances covered.

   Note 2 : OBES might also have some user communication facilities such as LCD display, buzzer, ...

   Note 3 : OBES must be autonomous, even if it might be also connected to the electric network of the car.

4. Computer System : The computer system consists in one or more computers, responsible for necessary invoicing and control of suspicious cases. The computers systems are called by cars asking for invoicing.

5. Automatic teller : Since the system is based on the prepaid concept, it is therefore necessary to create a network of automatic teller where token have to be bought.

IV.3. How the System Operates

1 All the cars are equipped with such a system.

2 Users should buy tokens using a special ATM. Tokens are stored on the smart Card. Transaction might be accesible by the IMERP computers system, wether on line or not.

3 When a user wants to use his car in an area where IMERP is in operation, he plugs the card into the card reader of the On Board Electronic System.

4 By passing through the gates, the reception system of the On Board Electronic System receives the signal permanently transmitted by the gates.

5 Depending on the nature of the signal and possible other information (time segment, day, etc ..), the Intelligent Electronic Board of OBES will debit a certain number of tokens from the smart card.

6 If the card doesn't have sufficient tokens stored in, then the Intelligent Electronic Board of OBES will keep in its memory the amount which will have to be paid by the user. This information will also be stored on the smart card, if present. A signal (buzzer, light, message ...) might also be sent to the user

7 If the card is not plugged into the card reader of OBES, then as in point 6, the Intelligent Electronic Board of OBES will keep in its memory the amount which will to be paid by the user, and possibly the fact that the card was not plugged at that moment (which will give a possibility to differentiate case 6 and 7). This amount might be augmented to penalize the negligence (if not the will to cheat) of the user . Other information might also be stored such as the area and date.

8 Each car is assigned a particular day in a period (e.g. a month), on which, if and only if debts are stored at that date in the memory of OBES, the telephonic system of OBES will call a particular number (and possibly other number taken into a list) also stored in the Intelligent board of OBES. This is intended to communicate with a computer of the Computer System of IMERP.

9 The communication being done, OBES will communicate to the computer the identification of the car, and the amount to be invoiced, plus (if necessary) information such as area, date and nature of infraction (e.g. presence or not of a card). Note that the quantity of

information being very small, the communication should therefore be also very small.

10 This transaction will trigger the invoicing of debts to the user. This invoicing will be sent by mail for instance. The computer will obviously deduce from the car identification the owner identification. Invoicing might include the price of the telecommunication, the price of the transaction, plus a kind of tax, in order to penalize invoicing.

11 The transaction will also erase all debts from the memory of OBES.

12 When the user uses an ATM to fill up his card, and if the card contains information following which he has a negative account in its own OBES, the ATM might warn him that he should take a sufficient number of token to take this debt into account.

13 When the user plugs again its cards full of tokens in the card reader of its OBES, and if debts are present in the memory of its OBES, then the Intelligent Board of OBES will debit from the card all those debts and then erase them from the memory.

Note 1 : Date of potential connection to an IMERP computer system should be evenly distributed on a chosen period (e.g. a month). In order to avoid communication traffic congestion, an optimal number **N** of computer shall be determined, in order to assign different computers to groups of cars.

Note 2 : Rather than a date, the criterion for the car to ask for invoicing might be of any another kind such as reaching a certain limit of credit, or being at certain place.

IV.4 Advantages of the system

A - **Technical** :

A.1. The system being widely decentralized, their is no more necessity of real time processing.

A.2. All the technologies are known and mastered technologies : smart card, electronic board, wireless communication, computer programs, ...

A.3. Due to the decentralized approach of IMERP, where all the system relies on the car itself, the problem of the multi-lane detection disappears.

B - **Operations** :

B.1. Cheat cars are no more a problem for IMERP. If the user doesn't pay with his card (on line of before the fated date of transmission) then the car itself will ask for an invoice.

B.2. If the user destroys his OBES and therefore doesn't pay for new tokens, the computer system can easily identify owners who are neither buying tokens nor paying invoices, which mean that either they cheat or they are not using their cars. This situation can therefore be checked.

B.3. If the user cannot leave the region covered by the wireless invoicing system in order to avoid invoicing. To do so he will have to pass through a gates sending a particular signal obliging, if needed, the car to ask for invoicing.

B.4. IMERP is a dissuasive system. Every thing is done to push the user to use his smart card rather that to rely on invoicing. The side effect is that only a limited number of transaction will be processed. This reinforce the decentralized aspect of IMERP. This dissuasion is graded in this way :

a) Normal uses of the system only provokes consumption of token on the card.

b) If tokens cannot be taken from the card, then a debt is memorized by the OBES. If the user fill up his card and pay its debts by plugging its card into OBES before OBES asks for invoicing, then the price to pay will be higher than in point a), even if the transaction does remain local to the car.

c) As soon as an invoicing process is necessary, the user will be charge for it also in a graded way :

c1 if the debts is due to the absence of token on a plugged card, the price to pay will be higher than in point b)

c2 if the debt is due to the absence of the card itself, the there might be a presumption of cheat and the user will even more charged than in point c1.

d) The user might also be charged for the transaction, communication, and mailing.

B.5. IMERP is a flexible system. New area can be put in operation in very short time, since gates are dumb are not requiring any

important public work. Another interesting characteristics of IMERP is that it allows the installation of temporary area of operation (e.g. dissuade the usage of a very particular place due to special conditions (e.g. event, exhibition, ...). Gates being very simple, they can perfectly be mobile.

B.6. IMERP can very easily be put in operation on other areas such as parking, highway, tunnel, ..., for instance.

C - **Ethics** :

C.1. The problem of privacy protection doesn't exist any more, since most of the transaction are made locally to the car. And if invoicing is needed, it is not more dangerous than a detailed telephonic one.

D - **Cost** :

D.1. The cost of design is very limited, each part being very simple. Gates are dumb one, and the key point relies in the design of OBES itself).

D.2. The cost of installation is also reduce dramatically :
- Gates are Dumb (very limited public work)
- Use of existing infrastructure (e.g. micro wave telephonic network).

D.3. Cost of operation is also dramatically reduced because of the fact that the main operation are occurring in the car itself without requiring the usage of a heavy infrastructure. The use of the computer system will be structurally limited due to the dissuasive nature of IMERP. Part or all of cost due to invoicing might be paid by the user himself and be part of the invoice itself.

D.4 *Last but not least*, the system being widely decentralised, the main part of it consist in the OBES, which cost might be partially or fully supported by the user. This is a big advantages of the system for the operator.

IV.5 Possible extensions

The flexibility of IMERP is one its characteristics.

1. Due to the simplicity of gates, new area can be installed (permanently or temporarily) in very short period of time. These are for example,

new areas highways, parking, critical area dues to special events (sport, ceremony, incident).

2. In a previous note we noted that OBES might perfectly be connected to the counter of the car, as a taximeter is. This connection should allow very easily to charge the user when he enters a specific areas, but also in using the roads of it (and depending on other information, such as time and date).

VI. Why and where the system is original

The originality of the systems relies on the simplicity of its components :

1. Gates are dumb and easy to install. All technologies are mastered

2. Existing public infrastructure are used. Their is no need to create new ones.

3. The car itself is the place where most of the transactions are made. The system is therefore a strongly decentralized one.

4. IMERP is a system very difficult to cheat with.

5. the main originality of the system relies in the hold over of payment and invoicing system :

   5.1 Smart card for immediate payment

   5.2 Local memory to keep track of debt, possibly paid later by a filled up card

   5.3 and if not the car ask for invoicing through its telephonic capabilities of its OBES, on a specific criterion (date, credit limit, ...).

6. The safety of IMERP (e.g. treatment of cheating cars) is guaranteed through the use of the original point of the system (point 5.3), i.e. the deferred call for invoicing made the car itself through its OBES system.

VII. What could be the potential problems of imerp

Even if technologies involved in IMERP are of very simple use, at least two point might be critical for the system :

1 - Technical :

If the wireless communication system used for invoicing is a telephonic one, there might be a problem of frequency distribution, and possibly a problem of quality of communication related to the power available for it in OBES itself.

2 - Cost :

Since the main part of IMERP as a system relies on the OBES, The cost of it is greatly dependent on the unit price of each OBES (even if the importance of this argument might be reduced thanks to the fact that the cost of each OBES might be supported by the user itself).

It is quite obvious that the main cost of IMERP will be due to the cost of the *sending communication system*. For instance, if celular telephonic system is used, the price will be higher than if CT2-like telephonic system are used (see article in appendix of this document).

Nevertheless, it might appear that, whatever is the telephonic system used, the price of it might be incompatible with the planned investment by the operator. Therefore, another sending communication technology (and operation should be proposed as an alternative to a telephonic one.

VIII. an alternative to the telephonic solution

The challenge is to find a low cost alternative to the telephonic sending system, capable to receive the information triggering the invoicing for users having debts memorized into their OBES.

1 - Detection loops :

This system might consist in simple detection loops (or gates) capable of reading the information possibly memorized in OBES. The technology needed to this purpose are simple, mastered and cost effective.

2 - Location of loops :

If the technology of these loops are perfectly mastered today, the problem is mostly to make sure that each car will eventually pass over one of these loops (within a reasonable time frame).

There is a simple and quite obvious solution to that problem related to a simple and quite obvious reason : "*Cars are using gasoline*".

Gas station are obviously the place where all cars without exception have to come. Loops can therefore be placed in gas station.

Note 1 : The detection of possible cheat cars (eg. user uses the tank of another car to fill up his own tank) will be operated in the same way than with the previous infrastructure. Being never invoiced and never buying new tokens, the user will be identified by the system as a suspicious one.

Note 2 : In order to reinforce the system, other loops might be placed at some other places (e.g. parking entrance, mobile control as far as loops are simple and mobile devices).

Note 3 : Since gas station are the place where all car have to come to fill up their tank, loops might only trigger (as gates) a simple and cheap transmission system embedded in the OBES.