"A NEW CONCEPT IN FREE-FLOW TOLLING SYSTEMS. PRACTICAL APPLICATION ON MEXICO CITY'S VIADUCTO ELEVADO BICENTENARIO"

Manuel López (mlvillena@indra.es)
Guillermo Pérez-Montero (gpmontero@indra.es)
Antonio Martín (amartin@indra.es)
Paulino Rodríguez (paurodriguez@indra.es)
Alonso Bautista (abautista@indra.es)
Department of Transport and Traffic, Indra Sistemas S.A., Spain-México

ABSTRACT

This involves the technological implementation of a closed toll system with controls at the entrances ramps and free flow at exits ramps. The implemented system allows reversing the operation. The most important technological innovation, besides the integration itself under a single system of dedicated toll lanes with free-flow gantries, has been based on the development of space-time correlation algorithms at the collection point, cooperative OCR algorithms, queuing theory in the control center, multi-platform applications, Web-based applications and middleware for communication between the different modules that produce a flexible and scalable architecture.

This system has been implemented in Viaducto Elevado Bicentenario (VEB) [1], and aims to join various areas of the north with the central area of the outer beltway of Mexico City. OHL Concesiones won the concession for exploitation, operation and maintenance of VEB. Indra Sistemas S.A.[2] has been responsible for the development and implementation of the comprehensive toll system (entrance lanes, exit gantries and control center) for the operation of the highway.

1. GENERAL DESCRIPTION

Indra is a global authority on Transportation and Traffic Systems, having implemented projects in more than 96 countries [3], which allows us to implement efficient systems to manage infrastructure (Intelligent Transport System (ITS)) and control revenues (tolls and electronic toll collection).

Fully automatic electronic collection systems (free-flow usually) for urban toll highways, provide a unique solution to ensure a reliable operation and control of the incoming traffic to roads with high demand and occupancy, as in the case of VEB. The solution proposed here is based on a mixed system with entrance lanes and exit gantries, while maintaining the philosophy of the electronic system, by controlling access with dynamic entrance lanes (validation and intelligent diversion) and charging a toll according to vehicle category and distance travelled (ticket system/closed tolls).

The main characteristics of the implemented system are the following:

- Each vehicle that uses the infrastructure must have a valid tag.
- For greater reliability, an OCR system was implemented to provide redundant validation of the tag and the license plate.
- To guarantee the access of vehicles with tags, high-capacity dedicated lanes for electronic toll collection will be available with escape lanes and the possibility of using PDAs to reincorporate vehicles with valid tags that were excluded due to a reader error.
- The exiting of vehicles is unimpeded through free-flow gantries for two lanes.

At the control center level, in the Toll Operation Center (Centro de Operación de Peaje [COP]), the data from the dedicated entrance lanes and the exit gantries are integrated with the following main functional areas:

- Transaction Processing System: management of transactions received from the gantries and trip compilation. The main processes performed are the following:
    - Reception, analysis and verification of the vehicles received from the gantries.
    - Reception of vehicles from the entrance lanes.
    - Trip compilation permits identifying the origin of highway exit transactions and setting charges as a closed toll.
    - Sending of the trips made to the commercial Back-Office.
- Management System or operations module: configuration, alarms, auditing and gantries management.

At the BackOffice level, centered on providing service to highway users, the most important functionalities implemented were the following:

- Customer and account management and billing.
- Website for customers: consultation of balances, transits made and payments.
- Main modules:
- Contact management.
- Tag management.
- List management.
- Generation of remittances and management of collections.
- Non-payment management.
- Billing process.
- Entity management.

2. ENTRANCE LANES

The entrance lane will be responsible for allowing access to the viaduct. This route will have two lane controllers. One, in charge of the main lane and the other in command of the diversion lane. The devices required to provide the necessary functionality will be added to these controllers.

Within the input system, we can functionally distinguish two parts, a first barrier with:

- Entrance information area: which indicates the lane status (open/closed) and attempts to identify if the viaduct is open in one or other direction.
- Identification area: Place where the vehicle identification takes place. Vehicles that enter the Viaduct are identified by their tags and licenses.
- Signaling area: Area where the vehicle is reported on its balance and the direction to take

The second barrier is a second chance for vehicles to validate the payment method; this is achieved using handheld readers that read the bar code associated with each tag.

The basic functions of the lane controller, for the entrance lanes, are described below:

- Presentation of the configuration and lane status.
- Presentation of the operator and lane identification data.
- Opening and closing time of the lane.
- Presentation of detected vehicles.
- Activation/deactivation of the keyboard or function keys according to the lane status.
- Association of the amount and category to the transit
- Association of payment methods to the transit.
- Association of crossing methods to the transit.
- Generation of an accounting sheet with transit data.
- Application closing control by authorized users.
- Communications with the Control Center.
- Graphical interface with the ability to display the status of all elements of the lane.
- License plate capture for subsequent recognition.

For each lane, there will be a process of data electronic load from the Control Center that will send a black list containing all invalid tags to each one of the lanes. Whenever the control center receives a new list, it will be distributed to all lanes. You can check what version of the list is loaded in each lane in the monitoring module.

3. EXIT GANTRIES

The exit system will consist of free-flow gantries capable of identifying the user through the tag including the necessary equipment for multilane vehicle detection using laser technology. A multilane configuration allows normal driving in the crossing area, at the speed of 90 Km/h (55.92 mph), and it permits the vehicles in transit to change lanes.

The main blocks of the free-flow exit gantries described here are:

- Multilane detection system based on laser technology : VDAC
- Image acquisition system with infrared lighting to capture the front image of the vehicle passing through the gantry, followed by an automatic license plate recognition system for Mexico : VES
- Communication systems based on DSRC 915 MHz valid for Mexico with antennas and transponder Mark IV (MIV) : ETC
- Gantry controller, consisting of a multilane controller and the general power supply and communications system: CP
- Metallic structure that hosts the hardware required for the correct operation of the free-flow gantry: GANTRY

The following figure shows a diagram with the mentioned blocks:

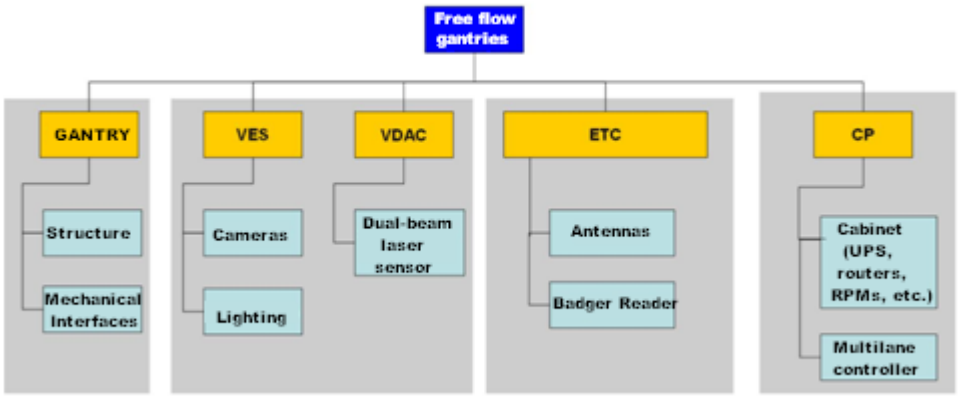

Figure 1. Block layout of the Free-Flow gantry

For the correct operation of the toll system, it is essential that these elements are properly integrated, and that they act in a coordinated way. The multilane controller core functionality is to monitor and synchronize all systems at the toll collection point. The matching of the vehicle information, provided by the communications and detection systems, is a critical task of the system and has to be conducted in real time.

4. CONTROL CENTER

The control center architecture, both hardware and software, is based to meet the following requirements:

- **Dynamic reallocation** of resources: servers allow the dynamically allocation of resources with the ability to take peak loads without increasing the hardware.
- **Optimum performance:** performance far exceeds the requirements, using the latest technology
- **Hot scalability** of the platform: servers will have growth rates of around 25% in its components. The extensions may be performed in hot, without stopping the operation.
- **Redundancy** in all components: all key components of the configuration will provide alternatives to potential failures.
- **High availability** configuration**:** the configuration includes High availability of the basic applications enabling alternative settings in case of failure.
- **Maximum use** of the components: the configuration will allow the active use of most components, remaining as pending only the minimum necessary ones, in the case of a possible incident.

Due to the existence of heterogeneous business processes, it is necessary to have inter-process communication methods and tools to graphically design the flow of business information. A message-oriented middleware platform is used to integrate all the systems. The use of this platform will enable agile development processes and interfaces between systems, providing the reliability, security, robustness and tolerance this type of system requires.

The part of the control center that is associated to the entrance lanes is responsible for storing the data generated in them, as well as sending the information lists and balances to them. In addition, it also acts as an interface with the BackOffice system and COP. The central server has a database that stores the data provided by the lanes.

Source Module	Destination Module	Description of relationship
Gantry	**Control Center**	Vehicles
		Images
		Alarms
Control Center	**Gantry**	Rates
		Balances and TAG lists

Table 1. Block layout of the Free-Flow gantry

In relation to commercial BackOffice, the system performs an integrated management of the toll activity and business processes of the highway, with the following main points:

- CRM system, enabling the customer and account management as well as the issuance of monthly bills, provided that it reaches a configurable amount. It also incorporates a customer website for inquiries regarding balance, transits made and payments.

- Interface to communicate the Back Office System with accounting ERP of the company holding the concession.

- Daily reports on traffic, trips by junction and route, as well as reports on creation and deletion of user and balances.

There is an application at the control center, a monitoring system based on web technology, MOMS, which allows monitoring the equipment condition and displaying real-time alarms, alarms that are occurring both in lanes as in the gantry, as well as the balance distribution process and processes of the center. When all alarms in the lane are of low priority, the alarm icon will be green. When any of the alarms of the lane is of high priority, the alarm icon will be red.

To visualize all traffic-related incidents at ITS, you have an application that acts as a tool to control inter-city traffic and to maintain the road equipment. This system is based on a distributed architecture based on the Client/Server model, which allows information from any road in any position of operation. It also acts on elements of the road, from any operator workstation.

This information will be, on one side, the equipment status data, such as signaling a PMV panel, or a camera interlocking towards a monitor. On the other side, you will see the alarms that may arise in said equipment, so the operator can detect them and act if necessary.

REFERENCES

1. www.viaductobicentenario.com.mx
2. www.indra.es
3. Other references:

Toll System Management and Web page for CONMEX	2008	• Tolling Management System. • Back-Office System. • Call Center • Web Page with general information. • Private webpage for Customers
Indiana Toll Road (USA)	2006-2007	• Back-Office system with customers accounts Management. • Call Center / IVR • Website implementation for general information and customers. • Reports generation system- Data Warehouse (Business Objects). • Electronic Toll Collection System. • CCTV system.
Americo Vespucio Sur ()	2003-2005	• Free flow system implementation. • Back-Office system implementation. • Data migration (accounts and tags) of the Free flow system.