SYSTEM FOR CONTROLLING ACTIVITIES

OF HIGHWAYS CONCESSIONARIES

MARTE, Claudio Luiz; Polytechnic School - University of São Paulo – USP; E-mail: claudio.marte@poli.usp.br; Website: http://www.ptr.poli.usp.br/ptr/docente.asp?d=22

FERREIRA, Maria Rosilene; Technological Research Institute of Sao Paulo – IPT. E-mail: mrosif@ipt.br; Website: http://www.ipt.br/centros_tecnologicos/CIAM

FONTES, Suelane Garcia; Technological Research Institute of Sao Paulo – IPT; E-mail: suelane@ipt.br; Website: www.ipt.br

SALETA, Alex; Regulatory Agency for Public Services Transport Delegates of Sao Paulo State – ARTESP; E-mail: asaleta@sp.gov.br; Website: http://www.artesp.sp.gov.br

GOUVEIA, Rui Fernando de Nóbrega; Regulatory Agency for Public Services Transport Delegates of Sao Paulo State – ARTESP; E-mail: rgouveia@sp.gov.br; Website: http://www.artesp.sp.gov.br

ABSTRACT

The state of Sao Paulo has much of its road network being operated by concessionaries, in which go through more than 60% of the state medium daily volume. It's important to bring out that 93% of cargo transportation is done through the road system and the Conceding Power is responsible for supervising the operation carried out by the concessionaries.

A lot of ways of action are used by the Regulatory Agency for Public Services Transport Delegates of Sao Paulo State – ARTESP , that is the organ undertaken by Conceding Power in order to inspect the concessionaries operation, such as: checkouts "in loco" inspection by outsourced staff, requirement for regular highway event reports and the concessionaire performances in these events, among others.

However, each concessionaire has information about the existing equipments and occurred events in the highways that are used in the operational controlling of the space below its concession, but Regulatory Agency (ARTESP) doesn't have direct access to this information.

All these action ways show the situation of the operation at a certain moment or a summary of what happened. However, the Regulatory Agency (ARTESP) has to answer to both the Public and the Government, many relevant issues, often immediately. In these cases, updated tools do not attend the needs, for instance when a huge traffic jam or a great proportions accident occurs.

Therefore, this research shows a support system to the operation of the conceded highways inspection, named ITS Module (*Intelligent Transport Systems*), which permits information's controlling about equipments and events occurred in highways through recuperated data integration of a lot of systems, from ITS and event maps used by concessionaries, generating alarms and alerts, when breaking level service or in adverse conditions.

MITS is an important tool for controlling the highways operation below concession by the Regulatory Agency (ARTESP). It is being developed by IPT (*Technological Research Institute of Sao Paulo*) and it is already deployed in some concessionaries in the state of Sao Paulo. Since the beginning of this decade, the IPT has been acting as a technological branch of ARTESP and during the period 2005-2007 developed a joint work with the Regulatory Agency, seeking the registration of the ITS equipment concessionaries state's highways. In addition to this work, in the period 2008-2011, MITS has been developed, so that on-line information of ITS equipment and event map of the state's first highway concessionaires can be obtained.

It was used to the MITS modeling the international standardizing, defined by ITU – T (*International Telecommunication Union – Telecom*), denominated RM – ODP (*Reference Model for Open Distributed Processing*) [ISO/IEC 10746]. The methodology RM - ODP was suggested at first by Becerra (1998), in 1997, and it was applied in the sub-architectures construction of ITS by Marte (2000). The RM – ODP was used to the logical project development (RM – ODP Enterprise and Information Viewpoints) and to the physical project development (RM – ODP Computational, Engineering and Technological Viewpoints) of MITS. In this article, it is explored the MITS physical project.

Keywords: ITS, RM – ODP, highway concession, regulatory activities, support system, TMC (Traffic Management Center), Regional Data Warehouse

INTRODUCTION

According to Doria (2008), despite the investments made systematically by the Government, the situation of the state's highways by 1998 was inadequate and did not follow the growth of traffic volume. Thus, the conditions of the roads have deteriorated, causing a large increase in transportation costs and endangering thousands of users.

In front of this context, the Sao Paulo State Government has searched in the concessions a solution to the road network which could free the state from these expenses, getting better the highway quality, guarantying a best security to the users. So, it was created the highway concessions "in order to rearrange the purpose of state action, allowing to the Public Administration the focus efforts on areas where their presence is essential, such as education, health and public safety". (ARTESP, 2009)

It was attributed to the concessionaries the maintenance and operation of conceded highways responsibility according to treated contracts with the State. There was also need to create an organ that would act not only as an inspector, but also as an intermediated among government, private companies and highways users. So, it was created the Regulatory Agency for Public Services Transport Delegates of the State of Sao Paulo – ARTESP, whose main role is to ensure compliance with regulations governing public delegates and ensure the enforcement of contracts between the state and private enterprise.

The main ARTESP actions concerning to the highway concessions are the edictal exigency guarantee: modernization and increasing of road network, accidents reduction programming, highway maintenance and operation according to the international parameters of quality. The concessionaire must attend determined levels of treated services in contracts between the concessionaires and the Regulatory Agency.

On the other hand, concessionaires have, in the stretch under their responsibility, equipments ITS that provide information both on specific data, as well as telemetry data from them. The technology set includes traffic sensors, variable message signs (VMS), closed circuit TV network, radio communications, weather stations, emergency telephones, surveillance systems for speed and weight and installed equipment in tunnels (anemometers, buttonholes hand and so on.) interconnected by fiber optic networks or wireless networks (using the infrastructure of the mobile phone companies).

Each equipment has a system to store and process its information. Eventually the same kind of system can deal with more than one device. Thus, each concessionaire has several systems that are not usually integrated. In addition to this, the systems are different from concessionaire to concessionaire, and when they are from the same supplier, in most cases, have different versions. In order to solve this problem of interoperability of systems, architecture was defined using an ITU – T (*International Telecommunication Union – Telecom*) methodology, which facilitates its development.

This reality is the same as that observed by Huisken and Goedvolk (2007) when they found that the centers TMC (*Traffic Management Centers*) were built with many technologies separated by traffic control, each of them composed of a collection system on the road, sometimes using a distinguished communication network (using a special protocol), with data stored in a database and information accessed by an application, both proprietary.

Beyond the united systems to the ITS equipments, the concessionaires have an event register system occurred in the highways. This great volume of information and systems bring other important question that is the standardizing of information considering that each one of the systems has different data structures and contents, although they have common characteristics.

In ambit of highway concession we have, thus, the concessionaire vision, that needs to control the highway operation and maintenance, having a focalized vision in the concession space below its responsibility; and the Regulatory Agency vision, that has the necessity to inspect all the concessionaires' actions. Besides, it needs the concessionaires' information in order to perform its tasks.

Due to the existence of such equipment and aiming to meet the need to obtain immediate and updated information, ARTESP asked the institute for Technological Research of Sao Paulo – IPT, which since 2007 is developing and implementing a support system for the supervision operation of highways, which includes, in a standardized way, online information equipment ITS and maps of events that occurred on highways (such as accidents, incidents of breakdown or electrical and mechanical assistance request, among others), generating alarms and alerts relating to breach of service levels or adverse situations.

This system, called Module ITS (MITS) allows the Regulatory Agency to oversee, at a distance and on-line form, the operation of concessionaire, responding to questions raised by the Government at any time, without having to question the concessionaries and provide information to the general public about relevant events.

The system definition is based on ARTESP knowledge about the business. In the ITS system and information modeling is used the international standardizing, defined by ITU-T (International Telecommunication Union – Telecom), known as RM-ODP (*Reference Model for Open Distributed Processing)* (Putman, 2001), that is based on" points of view" (or viewpoints) and in the UML diagrams (*Unified Modelling Language*) (OMG, 2007). The RM-ODP – multiple visions model becomes possible to the different partnerships of a project to observe the system by a convenient perspective and an adequate abstraction level.

INSPECTION ACTIVITIES SUPPORT SYSTEM OF HIGHWAYS

The support system to the inspection activities of highways (Marte et al., 2009) is inserted in a context in which we have the concessionaires, whose task is to control the highway's maintenance, the continued supervision of traffic and the guarantee of security to the users in highways. On the other hand we have the Regulatory Agency that has the task to regular and to inspect all the concessions.

Concessionaire

The concessionaires, for instance showed in figure 1, mounted a structure to collect taxes of toll, which is composed by three levels: level 3: Operational Control Center, that is responsible by administration of all toll places of concessionaire; level 2 – Operational Control Post (PCO), responsible by operation toll places and the level 1 – Racetrack, where occur the highway events, like toll collection, accidents, traffic and other ones.

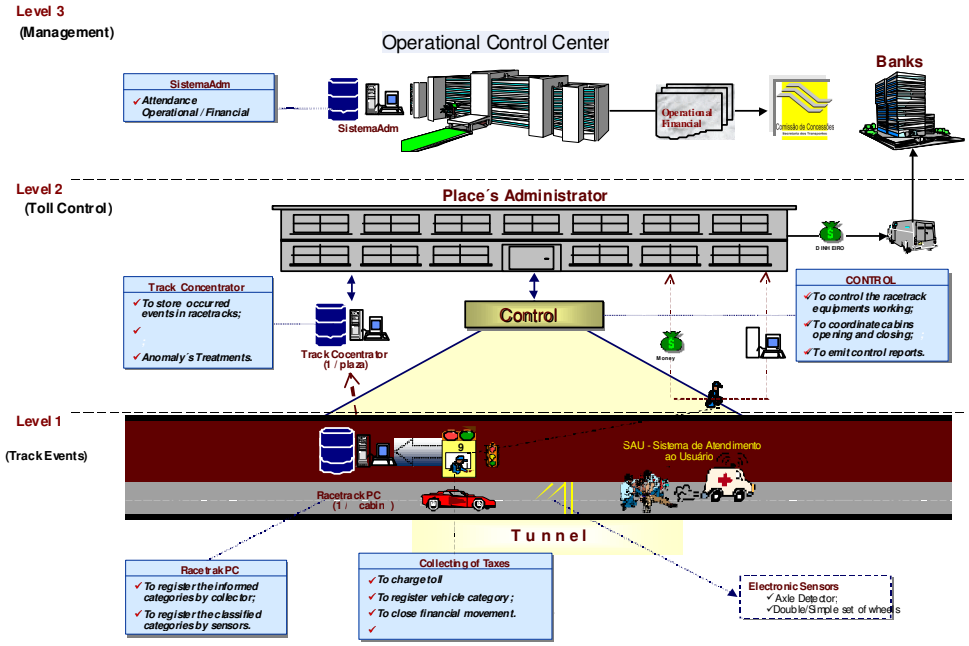

Figure 1: Concessionaire Overwiew: Toll Plazas Architecture

This way, doing the tasks of the edictals, the concessionaires have a whole of intelligent transport systems (ITS) which help in the highways operation. The technological whole includes traffic sensors, variable message panels (VMS), closed TV circuit, communication radio net, meteorological stations, emergency telephones, weight and speed inspection, beyond tunnels installed equipments (anemometers, buttonholes hand and so on.) interlinked by optical fiber nets or wireless (using the infra-structure of cellular telephony companies).Moreover, they have systems to the register of occurred events in highways.

The highway traffic routine monitoring and the actions of System of Attendance to the Users (SAU) are part of level 3, occurred in level 1, acting the necessary resources to the operational intervention, including other instances, such as Highway Police and Fire Brigade, when it is necessary.

According to Doria (2008c), all this modern technological display permits faster decisions and, because of this, physician and mechanic succour more efficient, reduction of quantity and gravity of accidents, more efficacious actions on controlling of traffic jams and increase of productivity and operational efficacious.

It is important to observe that information about occurred events in highways and the equipment situation are stored in data base of concessionaires and they are used by concessionaires only in operational monitoring. As the information is stored in centralized form, each concessionaire has its technological display and its operational control mechanisms and the Regulatory Agency does not have direct access to these information.

Regulatory Agency

The Regulatory Agency has to inspect the concessionaries activities and to guarantee the edictal accomplishment, mainly concerning to the attendance to the service levels, defined in contracts.

For instance of service levels to the toll plazas operation, defined in contracts, we can appoint:

1. Time of tax collect: Maximum of 12 (twelve) seconds, in 85% of cases considered in fiscalization. In the other 15% the time won't have to exceed 1 (one) minute.

2. Time of waiting in a line: It doesn't have to be more than 1 (one) minute in 85% of fiscalization done. In the other 15% the time won't have to exceed 5 (five) minutes at first year of operation and 3 (three) minutes in future years.

In order to perform its task are used a lot of action forms by Regulatory Agency. However, all these action forms show us the operation situation at certain moment or a summary of the things have occurred and didn't attend the present necessities of Agency.

It is important to detach that Agency, different from concessionaires, it isn't responsible by highway operation, but it is responsible to regular and to inspect the concessionaries actions. This way, it is necessary operational information being remained by concessionaires about the occurred events in the highways and the equipments situation as subsidy in order to verify how the action of each concessionaire is, monitoring the service levels established in contracts.

This way, the system MITS (Marte et. al, 2009) is being developed with the objective of obtain information originating of whole systems ITS and about the events occurred in highways of each concessionaire, centralizing the information in a only data base in Center of Information Control (CCI) of Regulatory Agency.

In an only system can be available information and statistics about the use and the availability of ITS equipments used in conceded highways of State of Sao Paulo; effectuate the registration of equipments localization, vehicles and edifications; the registration of information about toll (taxes, quantity of cabins) and inspection carried out; to monitoring the ITS equipments and services done by concessionaires and to permit to the Regulatory Agency to inspect the actions; to give information about the maintenance of equipments and about the concessionaires events maps.

MITS System

In order to understand the MITS system is necessary to get its magnitude problem involved. It's important to remember that this system has the objective to integrate information of a first phase concerning 12 (twelve) concessionaire companies. Each one of them has a lot of systems ITS and one map event system. These systems are from different suppliers and, even when they are of the same supplier, sometimes they have different versions. In order to solve this problem of system interoperability, it is defined an architecture that would make the development easy.

The MITS architecture, shown in the figure 2, is composed by a Central system, that will stay in the CCI of ARTESP, and a Process Agent (or updater) and an Adapter Agent introduced in the CCO of each highway concessionaire. With this, the relative specificities to the concessionaire systems will be solved in the ambit of Adaptor Agent, which access the information of basis of concessionaire, model the same and repass them to the Process Agent. The Process Agent is in charge of controlling the send of this information to the Central system in the CCI.

The definition of MITS is based on knowledge of ATESP about the business. It was used for the MITS modeling the international standardizing, defined by ITU-T, known as RM-ODP (*Reference Model for Open Distributed Processing*) (Putman, 2001), that is based on "points of view" (or viewpoints) and in the diagrams of UML (*Unified Modelling Language*) (OMG,2007).

The RM-ODP is a reference model defined on the ISO/IEC 10746 standard, which describes the necessary characteristics that a system of distributed processing needs to be opened. The RM-ODP – multiple views model – allows different participants in a project to observe the system in a convenient perspective and appropriate level of abstraction To this intend, consider the following viewpoints in the construction of distributed systems: enterprise, information, computational, engineering and technology.

The enterprise viewpoint focuses on defining the scope and objectives of the system, the information viewpoint defines the system behavior, in computational viewpoint are defined the system components and their interactions, engineering viewpoint aimed to define the physical distribution of the system and technology viewpoint aims to define the technologies and products to be used in the system, according to Farooqui, Lorippo and De Meer. (1995).

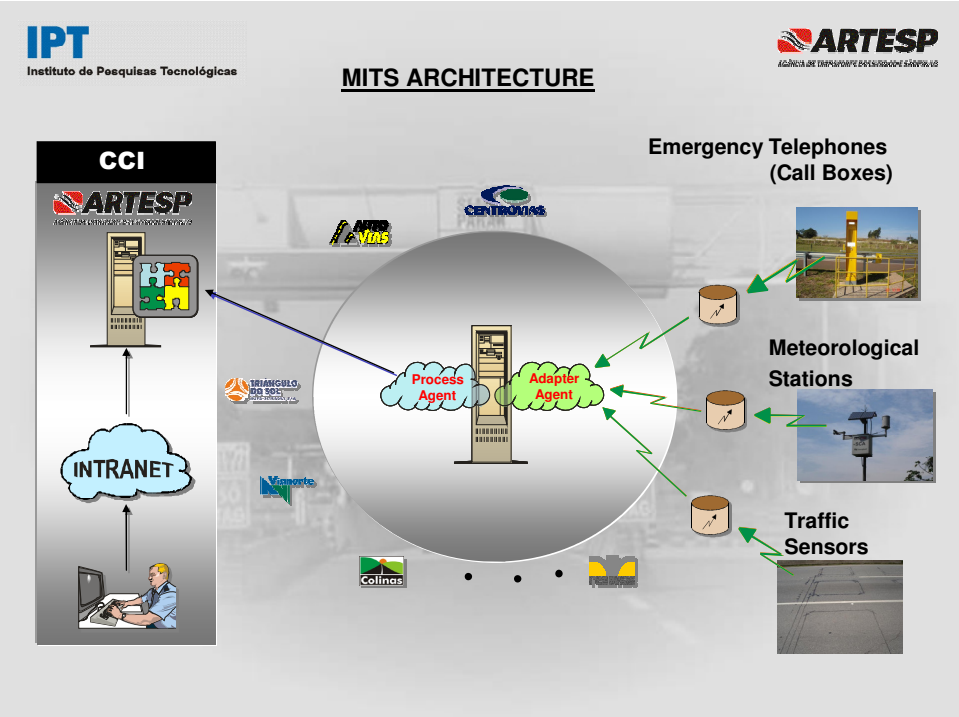

Figure 2: MITS Architecture

RM-ODP: Enterprise Viewpoint of MITS

It is an abstraction of the system, focused on the objective, scope and policies of the system and its environment, describing the business requirements and how to reach them, without worrying about software architecture, process or computational implementation technology. In order to help shape this vision are used Use Case and Package diagrams of UML.

The concepts covered, in the enterprise language of RM-ODP, include a Community of Users, the Federation of External Entities - represented by the highway concessionaires, other packages of MITS – represented by MIP (Toll Information Module), the access Policies and the own system under study.

In norm ISO/IEC-10746 (1995) federations are particular kinds of communities, in which different groups work together to achieve a goal, but respond to different authorities. Access policies or contracts determine the interrelationships of the elements (fields) described (the user community and associations) with the MITS. As in Marte (2000), they were divided into rules for sending data and rules for data transfer.

Based on the Enterprise Viewpoint of RM-ODP is shown – in the figure 3 – the interaction between the system and the concessionaries, with the other systems, with the intern users of Regulatory Agency and the extern users that are the Web public in general. We can observe, too, that the MITS will supply data for other intern support systems, which are found already in the Regulatory Agency. The MITS will be used by intern and extern users, respecting the access and transferring data policies.

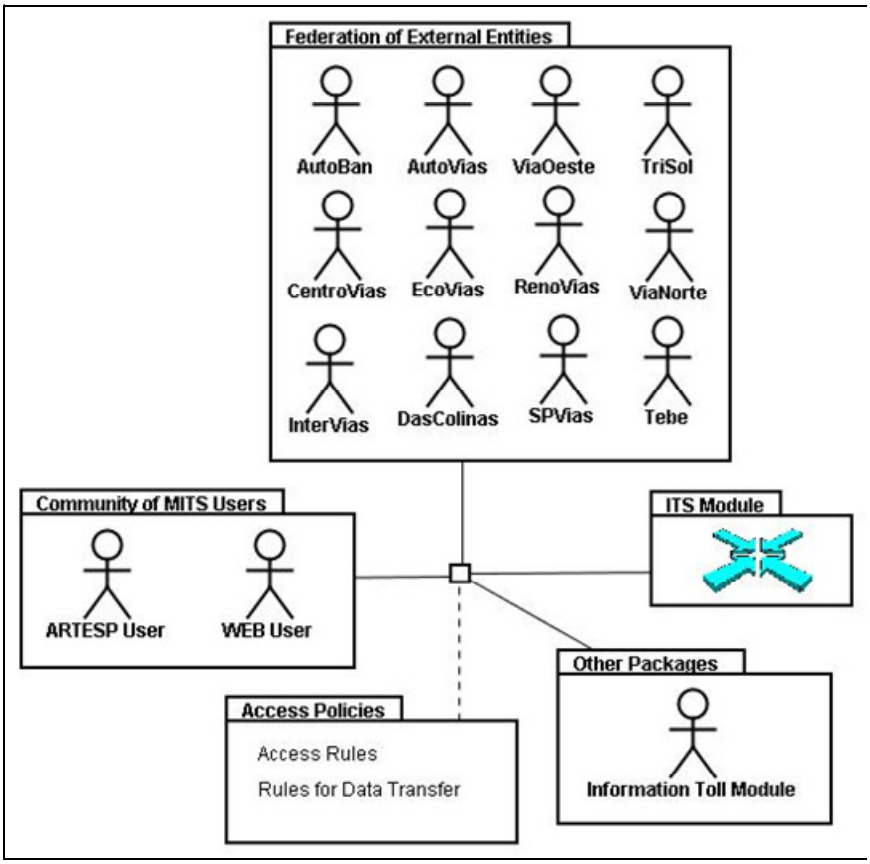

Figure 3: RM-ODP Enterprise Viewpoint: MITS Environment

The MITS is segregated in two different areas: the public and the private one. The public area has the objective of to available in the Internet, information about the traffic facilities and other things, with the focus in the common user the concessionaires' highways.

The private area has the objective to supply data that permit the Regulatory Agency to model the operation and the maintenance of equipments, vehicles and edifications, beyond of the occurred events of highway map.

Considering the scope of the system and its complexity, the features of the system, too, were organized in modules. Figure 4 presents the modules that make up the MITS system.

The Public Area available on the Internet for information to travellers on the highway concession, such as traffic, which includes consultation of the road conditions, accidents and construction, service to the user, which can be consulted on the location and services offered, consultation service number 0800, influence area the concession, cities nearby, roads and so on.

This Public Area will allow future users to access more complete information, not just a piece of concession, but all mesh controlled by ARTESP, anticipating a proposition made in Huisken and Goedvolk (2007) of a Regional Data Warehouse.

The Private Area is composed mainly by the modules:

- Monitoring of the equipment: which is responsible for the storage, management and provision of information from the concessionaries. This module will serve as a monitoring (and inspection) tool information to the Regulatory Agency, with information about alerts and alarms (telemetry) about concessionaire equipments.

- Map of the Operational Control Center: has the map information of events at the concessionaire.

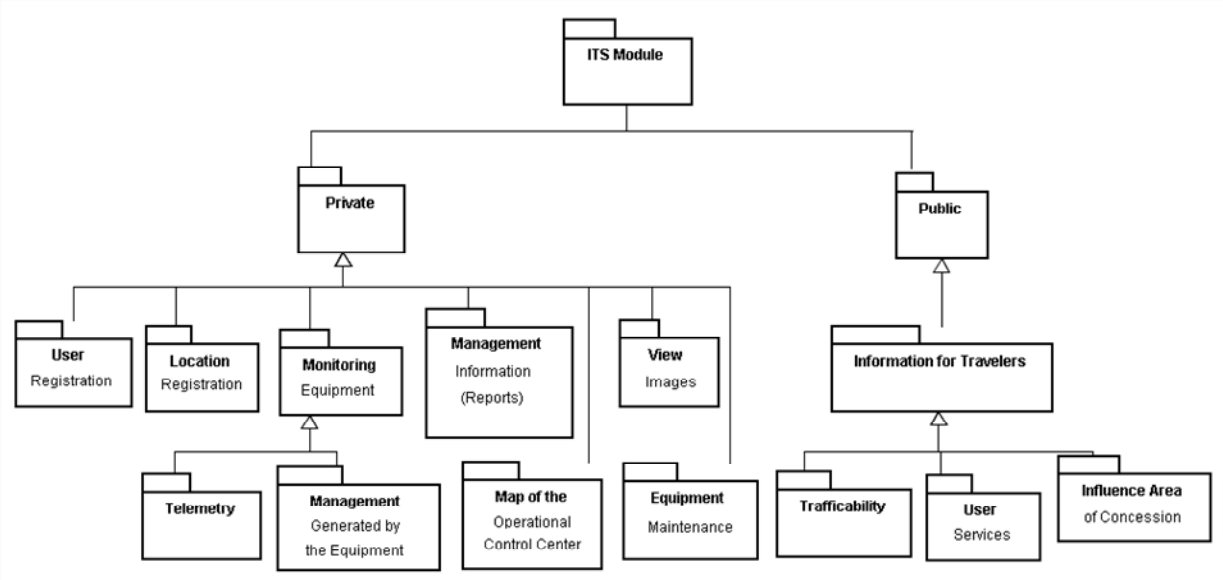

Figure 4: RM-ODP Enterprise Viewpoint: MITS Diagram Modules

RM-ODP: Information Viewpoint of MITS

According to Becerra (1998), the Information Viewpoint defines the system behavior. In this viewpoint semantics of information and processing system are defined, with the system requirements, according to the information stored and manipulated by business objects and the system, where access, location, persistence and transaction data should be made transparent to the user due to the concepts of distributed transparency of RM-ODP. It also describes the structures (or elements) of system information, restrictions and changes that must occur in these structures and the flow of information. For this vision are used Package Diagrams, Class Diagrams, Sequence Diagrams and Collaboration Diagrams of UML.

In this article, designed to give greater emphasis on Physical Design (Viewpoint Computational, Engineering and Technology), and simplification of RM-ODP Information Viewpoint to compose the MITS can summarize that data of the concessionaires will be captured and stored in standard database single in the Regulatory Agency, through agents adapters and updaters, responsible for the interface between the system and the various technologies available in concessionaries.

RM-ODP: Computational Viewpoint of MITS

Computational Viewpoint is the distribution of tasks to be performed within this system by mapping business objects and information objects in computing, which perform individual functions and interact through well defined interfaces, describing the implementation of the application and its components.

According to Moraes (2007), the computational viewpoint is defined as: a functional decomposition of the system in computational objects, computer interfaces that ensure the interaction between computational objects and computational models that define the behavior of interfaces.

In the Computational Viewpoint are used the following UML diagrams: Package – it is used to describe the relationship between the components, Activities – to represent the activities that affect the state of the system and the streams that lead from one activity to another; Class - to represent the types of data handled by components.

The object model of Computational Viewpoint consists of system architecture, its interfaces and the internal behavior of these interfaces. According to ISO/IEC-10746 (1995), the architecture of the system is responsible for showing how the configuration of the computer objects is done and how they are interconnected. Computational Viewpoint also describes the computer interfaces through its behavior. Based on Enterprise Viewpoint are describes the behavior of objects computing.

Computational viewpoint also describes how applications and distributed components of the RM-ODP system interact in a cooperative and transparent. The Computation language of RM-ODP defines the actions that an object can perform, providing that new objects and interfaces can be created and the links established. Thus, this language provides the foundation to enable open interoperability and portability of the system components.

The diagrams represent the interfaces in the object model computation of RM-ODP and represent a form of interaction between computing objects, showing that the MITS interfaces with the Highway Concessionaires and the Community of Users.

In the system architecture, as shown in Figure 5 - Computation Viewpoint of MITS, there are two packages: the Concessionaire and the Regulatory Agency. The concessionaire package is represented the database, from which they extracted the data, the database intermediate, where data is stored after being extracted and will be sent to the Regulatory Agency. We also report the adapter agent, that retrieves information from the concessionaire and stores the database intermediate of the Regulatory Agency and the devices for information transfer (web services), responsible for transporting information from the concessionaire to the Regulatory Agency.

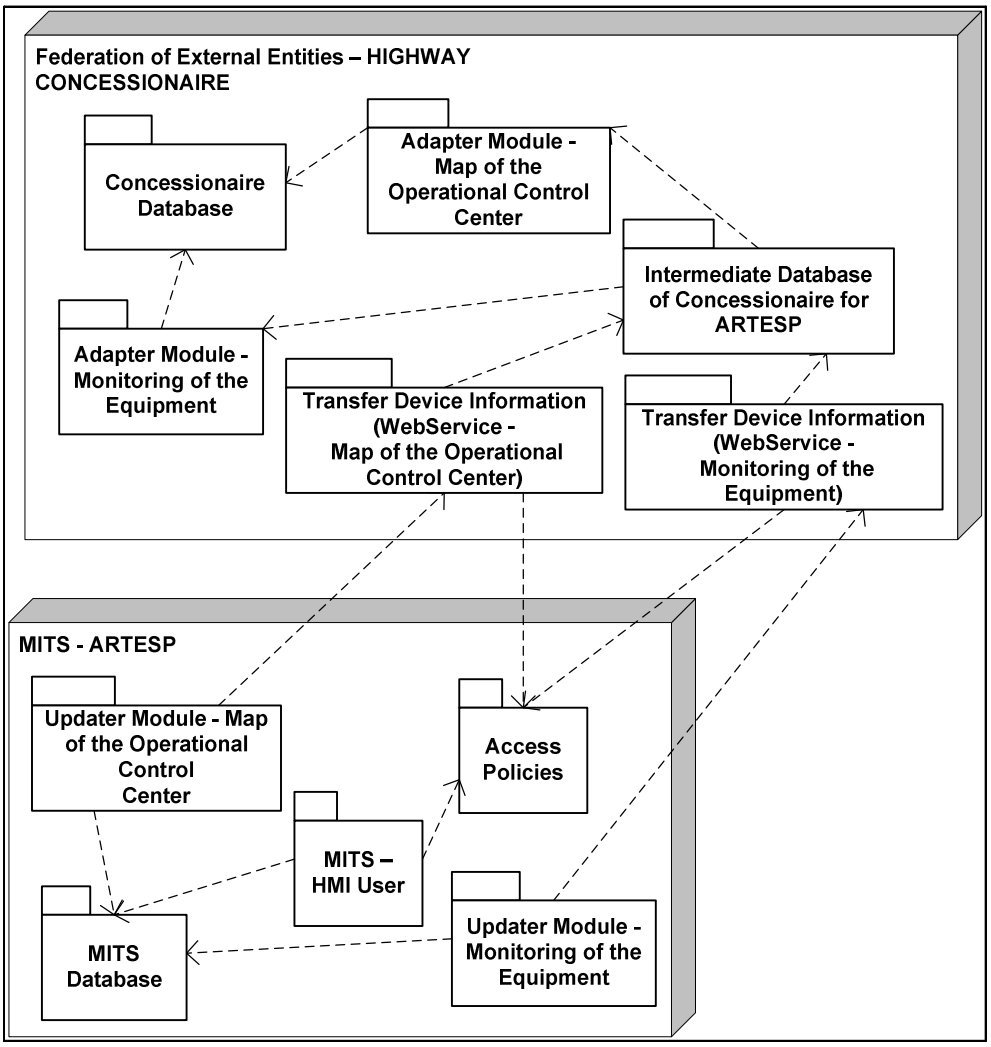

Figure 5 - RM-ODP Computation Viewpoint: MITS Package Diagram

Also in Figure 5, the package of Regulatory Agency lists the packages of Human Machine Interface (HMI) to interface with the actors who operate the system, users Web and ARTESP; the database of information system, where they are stored data on the equipment; the processing module (updater), responsible for retrieving the information in the middle of the Regulatory Agency and storage in the base system; access policies, which determine the restrictions on access and transfer rules information between the concessionaire and the Regulatory Agency.

RM-ODP: Engineering Viewpoint of MITS

According to Marte (2000) the specification of the Engineering Viewpoint complements the Computational Viewpoint, defining the mechanisms and functions required to support the distribution of computing objects. This view leads to a set of diagrams of objects, consisting on engineering objects and their associations. The specification uses the Computational Viewpoint because there is a direct correspondence with this, once the computational objects are transformed into basic engineering objects.

These objects can be compiled into an executable program *(cluster* or components) and can be run on a node. A node is a computing platform, which has a core or operating system, which allows those components to access functions or devices of this node. For the internal nodes Architecture at different levels, were hired Component Diagrams of UML, as Booch, Rumbaugh and Jacobson (2006).

The physical structure of MITS in Figure 6 shows the resources required for the interaction between basic engineering objects (RM-ODP Engineering Viewpoint) used by the system through the implementation diagram.

The data of the concessionaires will be captured / standardized through the Adapter Agent – Monitoring of the Equipment and the Adapter Agent – Map of the Operational Control Center and stored in an intermediate database of the Regulatory Agency, allocated at the concessionaire. The adapter is responsible for the interface between MITS and the various technologies available in concessionaires. This module will make the consultation of data on the equipment directly in the database of concessionaire and storage in the database intermediary in the machine of the Regulatory Agency.

The Adapter Agent – Map of the Operational Control Center is also responsible for interface between MITS and the different technologies available in concessionaires, but recovers and standardized information on events in highways concession. The Updater Agent (Process) - Monitoring of the Equipment through a web service, is responsible for capturing data on the equipment, the intermediate database, and send them, in configurable time intervals, for the Agency's headquarters.

The Regulatory Agency sent data will be processed and stored in the database system. The Updater Agent - Map of the Operational Control Center, differs only because the Updater Agent retrieves information about the events in the concessionaire, such as accidents, mechanical breakdown and so on.

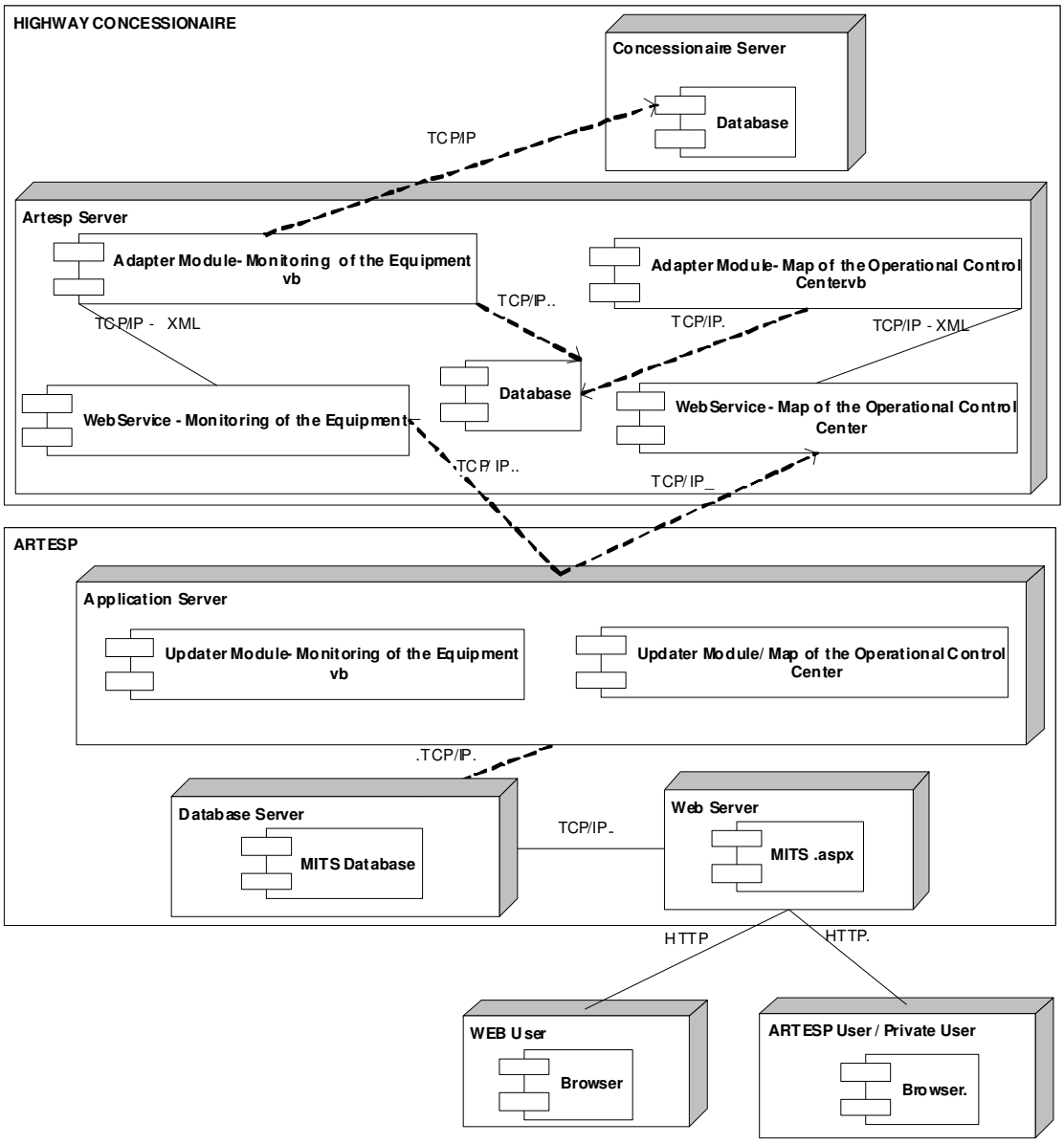

Figure 6 - RM-ODP Engineering Viewpoint: MITS Implementation Diagram

It is important to observe that the concessionaires have a lot of systems for storing information on equipment and events on the highway. Even in cases where the utility systems is the same manufacturer can occur storing different data. The concessionaires have specific characteristics of operation and are responsible for different highways, thus the stored information can vary. A certain information relevant to a concessionaire X can be considered irrelevant to the concessionaire Y. In addition to information, data managers and data types may also vary. Therefore, prior to development of agents adapters there is a phase of information gathering through an interview with the concessionaire, carried out by specialized analysts who seek to identify what information is relevant, since the data corresponding to these information are stored and are that can be recovered by MITS.

CONCLUSIONS AND FUTURE

Among the objectives pursued, the following results and conclusions were found:

- All Five visions of RM-ODP were applied on MITS architecture projects.
- It was possible to provide a system observation through a convenient perspective and appropriate level of abstraction to different team profiles by applying RM-ODP viewpoints on MITS project.
- MITS provides to ARTESP access to alarms (equipment telemetry information, miscommunication, open port, and others) and alerts (equipment information about events that can result in difficulties or problems in highway operation, such as traffic overload, average speed above limit) regarding the level of service breakdown between the concessionaire and the Regultory Agency; highway relevant events; ITS equipments with failure; and others. These information allow online remote supervision, making possible respond to Public Power issues at any time, without intervention of any concessionaire and provide relevant events information to the public.

The continuity of this work will be adding other ITS systems and integrate all the concessionaires of the State of Sao Paulo.

REFERENCES

AGÊNCIA REGULADORA DE SERVIÇOS PÚBLICOS DELEGADOS DE TRANSPORTE DO ESTADO DE SÃO PAULO - ARTESP. Available at: <http://www.artesp.sp.gov.br/servicos/concessoes/servicos_del_programa_concessoes.asp. Access: 14 – may - 2009.

Becerra, J. L. R. (1998). Aplicabilidade do padrão de processamento distribuído e aberto nos projetos de sistemas abertos de automação. Doctoral Thesis. Polytechnic School. University of Sao Paulo.

Booch, G.; Rumbaugh, J.; Jacobson, I. (2006). UML - Guia do Usuário, Editora Campos.

Doria, C. E. S. (2008). 10 anos de concessão. Available at: http://www.artesp.sp.gov.br/artigosDiretor/Artigo%205_10%20anos%20de%20concessão.pdf. Access: 27 – february - 2008.

DORIA, C. E. S. (2008b). Agências Reguladoras. Available at: <http://www.artesp.sp.gov.br/artigosDiretor/Artigo%208_Agências%20Reguladoras.pdf>. Access: 4 – july - 2008.

Doria, C. E. S. (2008c). Rodovias Inteligentes. Available at: <http://www.artesp.sp.gov.br/artigosDiretor/Artigo%209_Rodovias%20Inteligentes.pdf>. Access: 30 – july - 2008.

Farooqui, K.; Logrippo, L.; De Meer, J.. (1995). The ISO reference model for Open Distributed Processing: an introduction. Computer Networks and ISDN Systems. Available at: http://cserg0.site.uottawa.ca/ftp/pub/Lotos/TechRep/CNIS-94.pdf

Huisken, G and Goedvolk, H. (2007). Towards Traffic Management Centers of the Future. 6th. European Congress and Exhibition on ITSS (Intelligent Transport Systems and Services). Aalbrog, DenMark.

ISO/IEC-10746 (1995). Recommendation X.901/ISO/IEC 10746-1: Basic Reference Model of Open Distributed Processing – Part 1: Overview and Guide to Use. 1995. Available at http://standards.iso.org/ittf/PubliclyAvailableStandards/c020696_ISO_IEC_10746-1_1998(E).zip

Marte, C. L. (2000). Sistemas computacionais distribuídos aplicados em automação dos transportes. Doctoral Thesis. Polytechnic School. University of Sao Paulo.

Marte, C. L. et al (2009). Sistema de Soporte a las Actividades de Fiscalización de Carreteras Concesionadas. XV Congreso Argentino de Vialidad Y Transito.VIII congresso International ITS. Argentina.

Moraes, J. W. (2007). Roteiro para a aplicação da norma ANSI-ISA95 em conjunto com os conceitos de Sistemas Computacionais Distribuídos (RM-ODP), na integração do Nível de Manufatura com os Sistemas de Negócios (B2M). Thesis. Technological Research Institute of Sao Paulo – IPT.

OBJECT MANAGEMENT GROUP - OMG (2007). Unified Modelling Language Infrastructure Version 2.1.2. Nov. 2007. Available at: <http://www.omg.org/spec/UML/2.1.2 >. Access:14 – april - 2008.

Putman, J. (2001). Architecting with RM-ODP. Upper Saddle River: Prentice Hall PTR, 834p.