INTERNET OF THINGS ARCHITECTURE IN THE CONTEXT OF INTELLIGENT TRANSPORTATION SYSTEMS – A CASE STUDY TOWARDS A WEB-BASED APPLICATION DEPLOYMENT

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Abstract. *Radio-frequency Identification (RFID) devices are seen as the gateway to a new phase of development of the information society, known as the "Internet of Things". In this new phase, devices with reduced computational capacity will communicate over the Internet, generating large amount of information that adds value to everyday life. This will affect the relationship people have with everyday life, and the current business models. With this concept in mind, this study tests the viability of using an embedded system to control vehicle access from a University campus.*
Therefore, it will be used a low-cost, open source and Internet-ready platform, commercially known as BeagleBone to perform this local control. It should interpret signals from sensors, control an actuator - which is an automatic gate - and communicate over the network (using the standard protocols of the Internet stack - TCP / IP and Ethernet) using a simple LLRP middleware.
The main contribution of this work is to define the feasibility of using such architecture for more complex control and traffic monitoring possible applications, delimiting boundaries for the application of this architecture.

Keywords: *Internet of Things, Intelligent Transportations Systems, Radio Frequency Identification, Low Level Reader Protocol, Embedded Systems*

1. INTRODUCTION

The fast growth of world's population represents a major challenge, mainly to big cities, because of the amount of infrastructural problems that accompany it. Population growth brings problems related to urban sanitation, crime, pollution and transport. It can be noticed when analyzing large urban centers, such as São Paulo, which has in the chaotic traffic a relevant public problem. The Institute of Advanced Studies of USP estimated daily losses of 11 million reais in time and fuel in traffic losses, while the State Secretary of Metropolitan Transportation estimates that financial losses with accidents, pollution and congestion are around 4.1 billion reais per year (O impacto do caos nas ruas, 2008). Reduce losses related to transportation systems are on the strategic agenda of main cities of the world.

Modern approaches to solve these types of problems are understood in the context of Intelligent Transportation Systems, or ITS. ITS applications are inter-related systems of computers, communication technologies and management strategies to improve the safety and efficiency of transport systems (Kansas City Regional ITS Architecture, 2012).

Smart Cities are defined in (Ishida and Isbister, 2000) as connected communities that combine a flexible telecommunications infrastructure, with a network of services based on open standards and providing innovative services that meet every society. Efforts to bring intelligence to traffic and offer innovative services to society are closely related to these ideas.

In Brazil, one of the initiatives of the federal government to bring intelligence to monitoring and control of vehicular traffic is National System for Automatic Vehicle Identification, or SINIAV. The SINIAV project aims to implement an electronic identification system in vehicles, which works as an electronic license plate. The project also aims to implement a dedicated infrastructure that is able to read, interpret and communicate the data contained in these identification tags (Werner Von Braun, 2009).

The Radio-frequency Identification technology, or RFID, is the main enabling technology in this context. This technology allows electronic labels, constituted by a chip and an antenna, be energized by radio frequency emitted by readers and thus communicate with these remote reading units (Glover and Bhatt, 2006). Install electronic tags to identify vehicles with unique ID, and readers that can read it, opens up lots of opportunities for applications in vehicular traffic control and monitoring. Another project of the federal government that relies on the same technology is the project Brazil-ID. According to (O Brasil-ID, 2009) the project aims to "... develop and deploy the technological infrastructure of hardware and software that ensures the identification, tracking and authentication of goods produced and in circulation in Brazil, using RFID chips in order to standardize, unify, interact, integrate, simplify, reduce bureaucracy and speed up the production process, logistics and supervision of goods throughout the country."

The main contribution of this work is to establish a physical and logical architecture to a set of applications in transportation system focused in the Internet of Things. In this area of knowledge the major number of initiatives to create and deploy integrated, interconnected and scalable solutions faces the challenge to get frameworks and models to base developments. Therefore, this work has the following objectives:

- Considering the effort expend in the SINIAV initiative, establish a set of possible applications using the infrastructure provided by the project focusing the interoperability aligned with the mindset of the Internet of Things;
- With these applications in mind, propose a physical and logical architecture capable of offer these kind of software service;
- Develop and deploy a case study, focusing the vehicular access control, to demonstrate how a web-based software agent could be used to control a reader, sensors and actuators, via a unique programming language totally integrated with the Internet, in the MVC web development model.

2. INTELLIGENT TRANSPORTATION SYSTEMS IN THE CONTEXT OF THE INTERNET OF THINGS

Essentially, ITS services can be understood as a chain of information. Figure 1 shows this information chain. It includes data acquisition, communications, processing, data distribution, use of information and external factors (Chen & Miles, 2000).

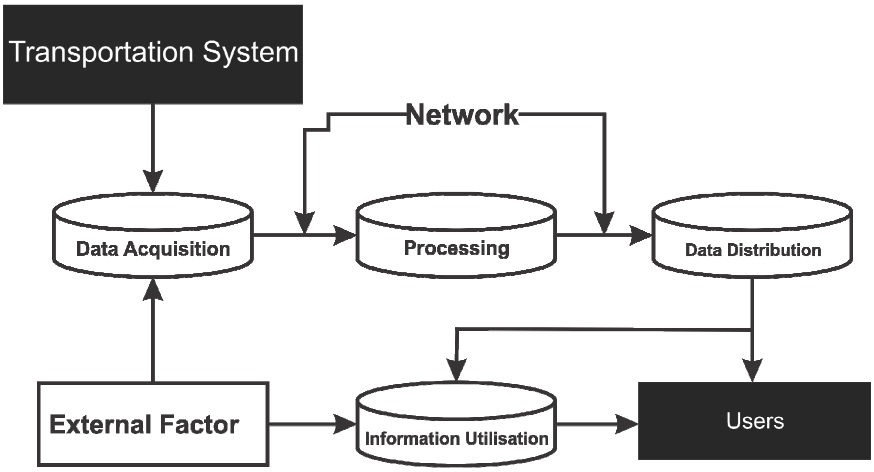

Figure 1. Information chain in ITS

It is a prerequisite for all ITS collect information from the transportation system. The Data Acquisition step is responsible for collecting data and represents them virtually. It is important that this information is reliable, accurate, and bounded in time. For this purpose various technologies are used, such as video cameras, radar, inductive loops, ultrasonic sensors and RFID. Note that these various technologies must complement each other to meet the goals of an ITS, and rarely is used only one type of technology in data acquisition. The most practiced is the adoption of various technologies to collect data. Climatic and meteorological analyzes are also considered as inputs in the chain, and are identified in Fig. 1 as external factors.

After the Data Acquisition step, the data must be reported to the processing units through a Communication Network. This network is mandatory in the definition and specification of an ITS system since it represents a significant part of the total costs. Normally, is not used a single physical medium to transport data from an ITS, and it is possible to find fiber optics networks and wireless communications coexisting on the same system. Typically, applications have different requirements of mobility and bandwidth required, which means that, for each application, different network architecture is used. Fact is, the greater the availability of communication infrastructure, the greater the amount of data that can travel over the network, and hence the better are the decisions taken by the system.

The information processing happens in a distributed manner. Databases and centralized servers are used to coordinate this network; however, decentralized units may work in smaller and specific applications such as access control, signage, vehicle counting and monitoring airway. In this scenario, embedded systems are widely used in lower processing tasks, and remote processing centers are constructed to focus data and coordinate these distributed systems. These centers are not only responsible for the information processing, but also for hold teams of professionals who monitor the Transportation System constantly.

Considering inputs (obtained in Data Acquisition) algorithms are executed (in the stage of Processing) and then the information is used for specific purposes. The data distribution is performed after data is processed, which generate specific results depending on the target application. These results should be distributed to fixed and mobile equipment that will realize the interface with users with valuable information. Among these devices, one can cite telephones (landline and mobile), monitors, handheld and vehicular radios, street signs and information kiosks. In future, we will see cars holding specific hardware to communicate with other cars and transportation infrastructure, offering in-place decision support information.

The Information Utilization serves some primary functions, which are not mutually exclusive. The first one is alert, directed used to get intelligent and coordinated decisions in determined situations. It is also expected that it support a system to control traffic and assist motorists toward cooperating with the relationship infrastructure and system users.

This generic model defines what are the elements that should be thought when adopting and implementing an ITS system.

2.1 Internet of Things

The Internet of Things is not yet a tangible reality, but a prospective view of a number of technologies, in the next 5-10 years, that could, combined, drastically change the way the societies work. The basic idea of the Internet of Things is that every "thing" of the physical world can become a computer that is connected to the Internet (Amazonas, 2011). Clearly, things will not become computers, but embed small computers. When it happens they are called Smart Things, and they can act more intelligently than things that do not have these computers (Fleish, 2010). Another concept that can be explored in this context is determined by the CASAGRAS2 project:

"The global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability to the basis for the development of independent cooperative services and applications. It will be characterized by the high degrees of autonomous data capture, event transfer, network connectivity and interoperability."

In the context of Intelligent Transportations Systems, the Internet of Things could impact directly. The amount of information collected by RFID readers, exchanged by cars (like Car-2-Car Consortium describes (Car-2-Car Consortium, 2012), and digital interfaces (like signalizations, mobile phone or in-car interfaces), will expand the possibilities of evaluate transportations systems by real processed data. It supports the decision making process with numbers and concrete facts, affecting planning and execution of public politics making it manageable.

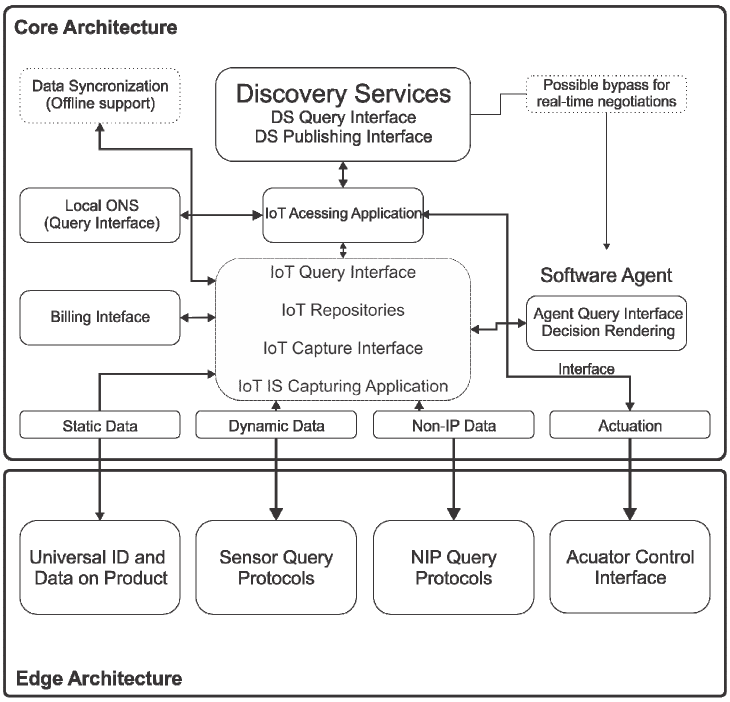

Figure 2. Reference Architecture adopted as a basis of development. Adapted from (Uckelmann, Harrison, & Michahelles, 2011)

But, since the information is collected by RFID Readers or capture mechanisms, like showed in Fig. 2, a lot of operations are needed. In order to build a scalable, adaptable and interoperable software agent capable of maintain and synchronize databases with valuable information is important to base the work in a reference architecture that could modeling macro tasks to reach objectives. Is important to note here that implementation challenges of actuation interface or information collection mechanisms are not the most important issues of this work. The main issue is how to turn it scalable and secure, in a way that several collaborated devices use the information to meet specific goals. How the information locally collected from the transportations system could affect the decision making process of other devices, is one of the question this work focus to answer.

With the above considerations in mind, Fig. 2 shows how this scalability can be reached. This is the initial reference architecture to develop applications with the Internet of Things mindset. It was proposed by (Uckelmann, Harrison, & Michahelles, 2011), and it isn't represent a structured framework to think the model, like the IoT-A project. But, it was adopted here in response of the need of a base to the deployment process. Therefore, it represents a relevant initial attempt and was buoyed with recommendations from the IoT-A project, being considered as the initial basis to development process.

Figure 2 also shows two main architectures, the core and the edge architecture. Edge architecture indicates the local data acquisition process, and the core architecture indicates how this information is stored, distributed and accessed by distributed agents. Databases synchronization is needed to offer offline support to the system and cloud database storage and processing possibility. Static data represents the RFID acquisition process, and actuation represents the agent responsible for making decisions. This general architecture also includes processes provided by the EPC global stack, showed in the next section, and predicts the need of an organized way to share information among the devices and servers.

2.2 RFID

The Radio Frequency Identification technology, or RFID, is a term that describes any system of identification in which an electronic device, attached to the item, uses radio frequency or magnetic field variations to communicate your identification number. The two most important components of an RFID system are the readers and RFID tags. The labels contain information and are fixed in the items to be scanned, however readers are devices capable of recognizing the presence of these labels (or tags) and read the information written on them. Usually readers run distributed software as an intermediary software layer between readers and applications. To these software agents are given the name of RFID Middleware (Glover and Bhatt, 2006), which will be detailed in section 2.3.

RFID devices are seen as precursors of a new phase of development of the information society, known as the "Internet of Things" - or IoT. In recent study (Wamba, *et al.*, 2009) explicit factors that influence decision-makers to invest in RFID as: (1) the benefits that RFID offers in terms of improving information quality, reliability and time savings, (2) the amount of top management commitment by senior managers to Provide resource that will support the investment in RFID; (3) improved alignment of information exchanged with customers and suppliers.

On the other hand, factors that negatively influence the decision for RFID investment mainly are (1) risks regarding privacy, (2) risks regarding the security and (3) ambiguous patterns. It also mentions that the opportunity to generate strategic benefits of RFID through improved decision making is critical. Although, it is clear that adoption is still broken by the costs of infrastructure acquisition associated with RFID technology. (Wamba, *et al.*, 2009)

In the context of applications related to Intelligent Transportation Systems, the adoption of RFID has been studied in the framework of the National System of Automatic Vehicle Identification, which is a project DENATRAN that determines the mandatory adoption of Radio Frequency Identification technology across Brazilian fleet of vehicles, which enables several applications under the control and monitoring of vehicular traffic. It establishes an initial bottom line to the work, once an infrastructure has been adopted to solve some problems related to traffic and transportation. It influences any try to envision a logical and infrastructural architecture to meet the needs of possible applications.

Establishing a parallel between SINIAV and ITS complete system, detailed in section 1.1, note that it defines clearly how it will be carried out data acquisition system of transportation. The biggest concern of SINIAV is to standardize and specify the tags, readers and antennas (and tag access protocols with encryption and good response performance) that will be used to collect information from transport systems.

2.3 Middleware

The protocol architecture treated in Fig. 4 identifies all the steps of RFID communication, according to EPC Global. The information goes through these steps from the moment that the reader performs the reading of a tag until it is shared by agents among the information chain. The LLRP protocol is the basis of this chain, it represents an attempt to standardize the way readers communicate and configure their operations. Before, proprietary tools were used to accomplish these tasks, making the interoperability between distinct manufacturers a hard task. This lack of interoperability between heterogeneous systems - once a Motorola reader could not easily be replaced by an Allien, for example - does not allow an Internet of Things develops, and radically affects the scalability of RFID systems.

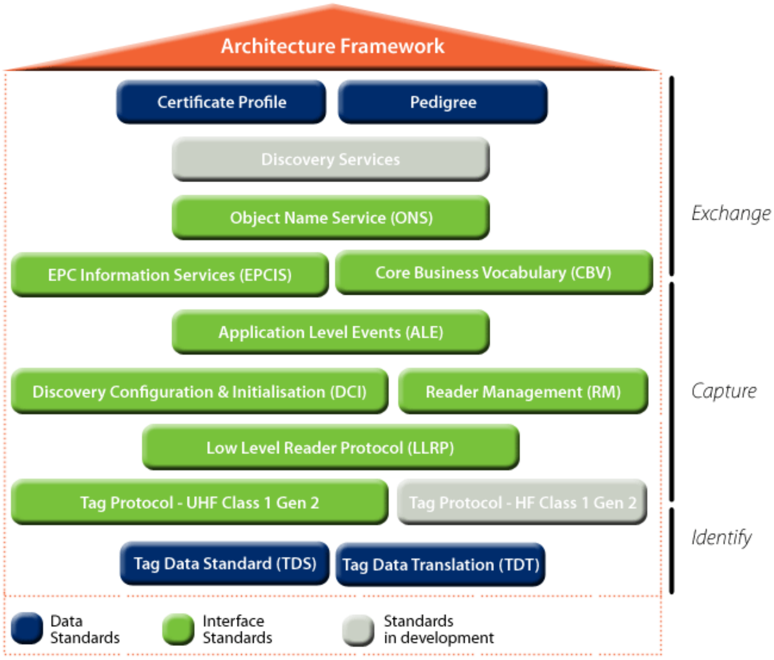

Figure 3. Architecture Framework proposed by EPC Global. Source: (EPC Global, 2010)

As shown in Fig. 3 EPC protocol stack used to directly control the reader is the Low Level Reader Protocol, or LLRP. It is responsible to configure reader operations tag access operations. In addition, a middleware contains logical mechanisms for filtering and aggregate tags, and it is defined by the Application Level Events Protocol, or ALE. The basic idea of ALEs engines is to provide filtered and aggregated data for applications which can be directly used by the applications.

Regarding the acquisition of data from RFID system, compared with the architecture suggested by Fig. 3, this work does not fully implements filtering procedures as described by the ALE Protocol, understanding that the need for filtering and aggregation in these cases is a secondary factor for concerned applications and also for a preliminary case study. This protocol is of great importance and interest in RFID implementation and should be understood when implementing professional applications.

A reader and a client interact to achieve the goal of inventory tags, through structured messages exchange. At first the client configures the reader concerning the operation to be performed. Then configure the operation of each antenna (especially regarding how these antennas will inventory tags), and also the way tags are accessed (air protocol to read and write tags), specified by the Access Rules Setup. When done, the reader will come into operation by sending the client status in cycles determined by messages exchanged. At the end, the reader sends a final report to the client.

In this case one can discuss the use of LLRP protocol in this work, together with some simple filtering features, from the following points:

Communication with readers is relatively simple when using programming tools like LLRP Toolkit (LLRP Toolkit, 2008) and this work uses the proposed device like a bridge that catch information, filter it fast, and send to remote databases;

Commercial Implementations or open source middleware platforms are made for higher processing capabilities platforms. This study consider that, for an ITS, a big number of applications will be running remotely, in embedded networked platforms, where the RAM memory is a restrictive factor;

A complete middleware developed focusing on compact systems, particularly for the Raspberry Pi platform, known as RiFiDi was released recently. According to the documentation it only supports one reader manufacturer, showing that this solution is not completely consolidated.

The LLRP protocol is based on two main abstractions: 1) Read operations and 2) Access Operations. Read operations - or RO - define parameters for the operation of Inventory and Research of Radio Frequency antennas. Access Operations define parameters for operations of data access from and to the tag. (EPCglobal, Low Level Reader Protocol (LLRP) Version 1.1, 2010).

Operations starts and stops are performed using the specification limit, which determines how a transaction has to initiate (via an initial trigger) and be completed (via a stop trigger).

2.4 Impacts

The impacts of determining such an architecture focused on Internet of Things is directly related to the applications that can be envisioned using this architecture, accordingly the IoT-A project, this is the initial step to build a Reference Architecture to IoT applications. Among the applications that can be envisioned with this mentality, one can mention:

- Control of vehicular access to restricted sites using cloud architecture. In this case the data would be collected locally and sent to web services in the cloud, so that is offered a web or mobile interface to interact with the system. Thus, a restricted site (as condominiums, parking lots or public buildings) with the installed system can offer services through the Internet. It can optimize security, organization and time usage on these sites;
- Congestion forecast and information to ITS users. Crowdsourcing services like Israeli *Waze* and Brazilian *Wabbers*, is gaining popularity by offering a navigation GPS platform for users who want to know the traffic at the moment. A prediction jams tool can complement this service, providing more accurate and automatically acquisition of data to provide services to users (Al-Naima and Hamd, 2012);
- Detection of stolen vehicles or with unpaid taxes, and information of this data to authorities. This allows real-time viewing through web or mobile tools, of illegal vehicles. They are identified when passing in a monitoring station, or even by readers located on public roads;
- Estimated time of urban public transport and providing this information to the public through modern technologies related to Internet and Mobile devices. The operation of such a system requires that bus stops are equipped with RFID readers and then information collected at these points to be used by an application. Knowing the predetermined route for a given line, the information is updated in real time, allowing applications to provide updated schedule information (Vanitchakornpong, *et al.*, 2012);
- Logistical access control of trucks sites inside companies, harbors, airports, and railway terminals; through transfer of relevant information between the agents of the same supply chain. In this case, a logistic oriented application with relevant value added, also helps the exchange of information through the supply chain, could work by aggregating products data in tags transported by trucks. So a truck can provide this information to distinct business agents in the same supply chain, thereby addressing the problems of non-compatibility between the flows of information and materials.

3. WEB-BASED APPLICATION

The case study using the concepts treated on this work was designed aiming the vehicular access control application. A web-based embedded application was developed considering all possibilities cited in section 2.4. Some features can be highlighted, and it impacts this system as development requirements:

Decentralized infrastructure with the usage of RFID readers in physically far locations, which characterizes a distributed system in which several devices work together to serve a single purpose;

Need for processing data that will be sent by remote agents for remote servers as well, which gives us the opportunity to use cloud architecture for processing such data;

The usage of RFID readers in the context of the Internet, instead of an internal network (intranet) in distributed applications requires the insertion of a security layer to the communication. It generates a demand of inclusion of security mechanisms to the local system that will be used for these applications.

These requirements, together with the reference architecture showed in section 2.1, results in the physical architecture proposed by Fig. 4.

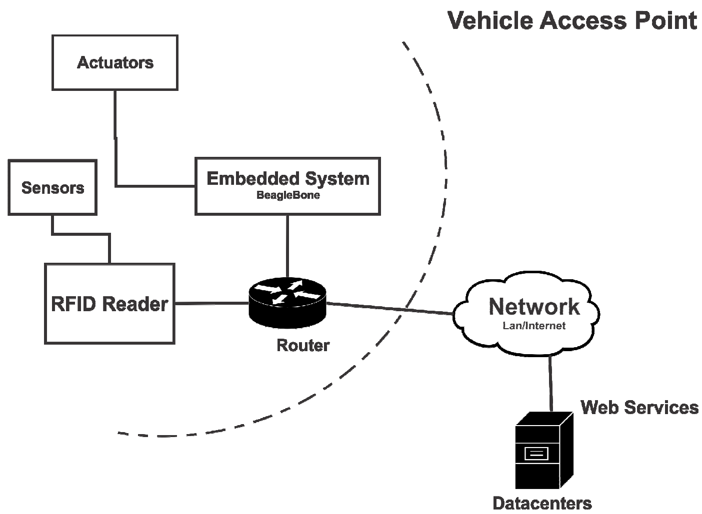

Figure 4. Local physical architecture used in the case study

An internet-based application allows devices get remotely configured through the internet, allowing remote configuration and support to these devices. The information provided by devices can also be processed and stored by cloud services, which allows Big Data processing and data mining. That way, there's a huge opportunity to measure data from transportation systems, enhancing the quality of public politics on this area.

Comparing the logical and physical architectures, proposed respectively by Fig. 2 and Fig. 4, one can better understand the system in question. The controller will be responsible for the acquisition and communication with the RFID reader, and interface sensors and actuators also, being a complete system for data acquisition and actuation interface based on IoT Repositories.

All elements of the system will be allocated in-place, except the *Web Server*, as is shown in Fig. 4. The function of this web service is to collect and aggregate all system information and improve the scalability of local clients. To add a new car to be managed by this Web Service, just a new user is created, making replicas of the system easily made, reducing costs with installation and system support. It enables the use of modern business models such as Infrastructure as a Service, or IaaS, Software as a Service, or SaaS and RFID as a service, or RFIDaaS as analyzed in (Uckelmann, *et al.*, 2011)

3.1 Implementation

This work uses an open source, low-cost and Internet-ready development platform, commercially known as BeagleBone. On the platform was installed a reduced version of Linux operating system focused on embedded systems, named Angstrom (Support Resources, 2011). The main criteria to choose the platform used was the alignment with the mentality of the Internet of Things (Uckelmann, Harrison, & Michahelles, 2011). This platform is open-source, in hardware and software, what reduce the development costs. Moreover, it has native Ethernet communication and support to Secure Shell Clients, or SSH, what makes the communication with remote units easier. All these factors have motivated the choice of this platform as a basis for the development of this work.

When using an embedded operating system to implement more complex applications, care should be taken in the use of RAM memory and processor (Support Resources, 2011). Volatile RAM memory and the processor's computational capacity are restricted, and any delay in the system is seen by the user as a failure.

The programming language chosen in this case is Java. Reasons for this choice are: flexibility with respect to the operating system that will use and ease of implementation, automatic memory management, and object-oriented programming paradigm, what makes the development easier in case of more complex systems deploys. Following the MVC model, the play framework was chosen to all implementations.

The local controller needs to host a database to store information not yet synchronized. When the data acquisition is performed the software holds the information, and tries to send it to remote databases (in this case to cloud databases). MySQL is the most used database engine around the world, and many Linux systems use it. In this case MySQL was used due ease-to-develop criteria, and synchronization with remote servers ability. It is also an open-source database engine, which is also a relevant point since the interest is to develop an *Internet of Things* compatible system.

It was used a UHF RFID Reader Motorola Symbol FX7400 with AN480 antennas to test the concept proposed in this paper. The reader communicates with the controller using Internet protocols. The mode of operation and message exchange is made possible by the LLRP protocol. The LLRP message exchange is viable through the usage of, the SOAP and HTTP Application Layer Protocols (in OSI model), through the exchange of XML messages (EPCGlobal, Low Level Reader Protocol (LLRP) Version 1.1, 2010)

The LLRP protocol is a standard defined by the EPC architecture. This is the most direct way to control a reader through an Application Programming Interface – API – that allows implementations to configure the operation of a reader. It is possible to collect information from tag readings without the need to install a complete *middleware*, what provides a higher number of tools to developments. It affects a critical project requirement, which is the usage of system's volatile memory (RAM), once a not full featured middleware will not be used.

It is used sensors and actuators that provide an interface between users and the system. They will be connected to the system's controller through GPIOs (General Purpose Input / Output), and it is responsible for monitor the operation of the actuators and sensor.

When a vehicle is positioned to access the site covered by the system, the presence sensor detects its presence, then a read cycle is initiated by the RFID reader. The tags within the field of view of the antennas will be read and sent to the controller. With this information the controller makes decisions and trigger actuators, which are automatic barriers and electronic signage. The barrier sensors are also responsible for preventing the barriers to close and damage vehicles.

An application on a remote server, called web application, should be responsible for providing some important services to the system, as follows:

- Maintenance of databases of registered users and systems events (Note that the presence of a database of events in the system allow future usage of Big Data and Data Mining techniques);
- User's and Administrator sign up and sign in interfaces, and client services;
- Database synchronizations;

At the present time, only the client side was implemented. It is possible to develop only this part of the system without significant functionality losses when considered a case study focused on determine a possible architecture to ITS applications.

A play application follows the MVC architectural pattern applied to the Web architecture. This pattern splits the application into separate layers: the Presentation layer and the Model layer. The Presentation layer is further split into a View and a Controller layer.

- The Model is the domain-specific representation of the information on which the application operates. Domain logic adds 'meaning' to raw data (e.g., calculating if today is the user's birthday, or the totals, taxes, and shipping charges for a shopping cart). Most applications use a persistent storage mechanism such as a database to store data. MVC does not specifically mention the data access layer because it is understood to be underneath, or encapsulated by, the Model.
- The View renders the model into a form suitable for interactions, typically a user interface. Multiple views can exist for a single model, for different purposes. In a Web application the view is usually rendered in a 'Web format' like HTML, XML or JSON. However there are some cases where the view can be expressed in a binary form, e.g. dynamically rendered chart diagrams.
- The Controller responds to events (typically user actions) and processes them, and may also invoke changes on the model. In a Web application, events are typically HTTP requests: a Controller listens for HTTP requests, extracts relevant data from the 'event', such as query string parameters, request headers, and applies changes on the underlying model objects.

Figure 5 shows how the systems communicate with the devices, remote databases and users to carry out the most important objectives of the system.

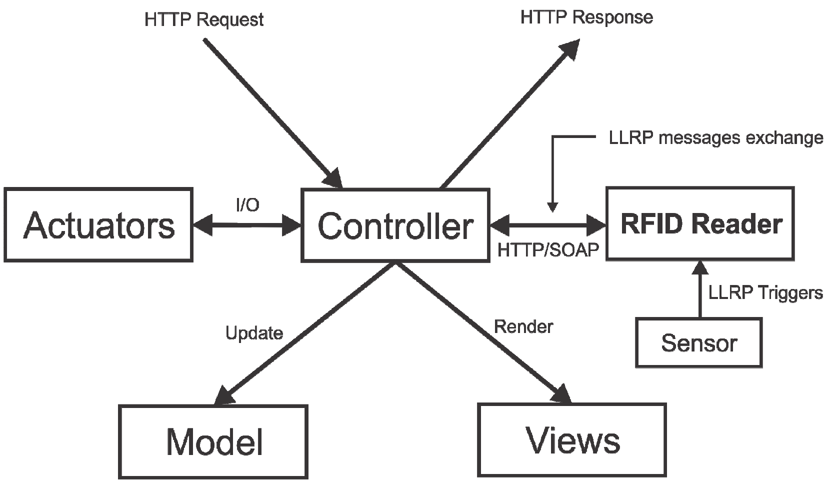

Figure 5. Interaction between main devices and communications interfaces.

3.2 Results

The software deployed in this case study to understand the feasibility of such architecture in applications described in section 2.4 above showed good results in initial tests. Through a unique implementation was possible to read tags, run a web application to register new users and tags, measure sensors and control actuators. At the moment, only workbench tests were performed to test the initial implementation.

Evolutions in the direction to have an ease to scale application capable of provide resources to all applications mentioned in this work are needed. The initial case study proposed by this project is a good base to a continuous software deployment aiming to reach all derivate requirements from complex applications.

The IoT mentality inside the context of the Transportation Systems is a huge area of development. This work focused to start the discussion from envisioned applications and current projects that influence project's requirements, as recommended by the IoT-A project (IoT-A, 2012). In this case, the proposition of a logical and physical architecture is yet a tangible result of this work.

4. CONCLUSIONS

The Internet of Things is becoming a reality in the world as we know it today, and despite the research that ultimately seeks to anticipate what is to come, not always followed the adoption trends as expected. At this point it is concluded that it is always important to approximate the research, with the largest die merchandising applications, and generate business value. For this it is necessary to recognize the multidisciplinary nature of this area so that progress in technology research is followed by basic research to ensure the adoption of these technologies over time.

Furthermore, it is concluded that the adoption of physical and logical architecture proposed in this work still requires study regarding the performance of the hardware chosen, especially with respect to safety, response speed and storage capacity. It is hoped that ongoing implementations can answer these questions and define boundaries for the applications in question. However, it is still necessary to understand the impact caused by legal adoption, especially with respect to privacy and use of information third.

Finally, it is argued that the Internet of Things and the applications that come derived from the technologies involved, can positively impact on several areas, having a great potential impact on society and the creation of value to the business. Determine business models that support this adoption represents a major challenge, especially for the fact that the value of this impacts several stakeholders simultaneously, thus increasing the complexity of these models.

5. REFERENCES

Al-Naima, F. M., & Hamd, H. A. (2012). Vehicle Traffic Congestion Estimation Based on RFID. *International Journal of Engineering Business Management*.

Amazonas, J. d. (2011). Introdução a Internet das Coisas. In: F. Hessel, R. S. Villar, R. R. Dias, & S. D. Baladei, *Implementando RFID na Cadeia de Negócios* (pp. 201-227). Porto Alegre: ediPUCRS.

Barrero, F., Toral, S., Vargas, M., Cortés, F., & Milla, J. (2010). Internet in the development of future road-traffic systems. *Internet Research*, 154-168.

Car-2-Car Consortium. (October of 2012). *Press releases*. Acesso em 15 de May de 2013, available at em Car-2-Car Communication Corsotium: http://www.car-to-car.org/index.php?id=20

Chen, K., & Miles, J. C. (2000). *ITS Handbook 2000 – Recommendations from the World Road Association.* PIARC.

Constantinou, F. (June of 2007). An Object Oriented Implementation of a Low Level Reader Protocol (LLRP) Library. Departament of Electrical Engineering and Computer Science - Massachusetts Institute of Technology.

DENATRAN. (07 Apr. 2011). *Portaria Denatran 570/11.* Access at 06 Aug 2011, available at em DENATRAN - Departamento Nacional de Trânsito: http://www.denatran.gov.br/siniav.htm

EPCGlobal. (13 Mar. 2009). The Application Level Event (ALE) Specification, Version 1.1.1. EPCGlobal Standard Specification.

EPCGlobal. (Oct. of 2010). Low Level Reader Protocol (LLRP) Version 1.1. EPCGlobal Standard Specification.

Fleish, E. (2010). What is the Internet of Things? An Economic Perspective. *Auto-ID Labs White Paper*.

Floerkemeier, C. (2008). *Integrating RFID Readers in the Enterprise IT - Overview of Intra-organizational RFID System Services and Architectures.* Cambridge: Massachusetts Institute of Technology - White Paper.

Fórum de Competitividade de IoT. (Jul. 2011). *A importância da Internet das Coisas para o Brasil.* Access at 14 Dec. 2012, available at Fórum de Competitividade de IoT: http://www.iotbrasil.com.br/wp-content/plugins/download-monitor/download.php?id=1

Glover, B., & Bhatt, H. (2006). *RFID Essentials.* Sebastopol: O'Reilly Media.

IoT-A. (14 Nov. 2012). *Converged Architectural Reference Model for the IoT v2.0.* Acesso em 23 de May de 2013, available at em Internet of Things - Architecture: http://www.iot-a.eu/public/public-documents/documents-1/1/1/D1.4/

Ishida, T., & Isbister, K. (2000). *Digital Cities: Technologies, Experiences, and Future Perspectives.* Berlin, Heidelberg: Springer-Verlag.

Kansas City Regional ITS Architecture. (5 de May 2012). Access at 15 de April 2013, available at Mid-America Regional Council: http://www.marc.org/transportation/ITS/index.htm

LLRP Toolkit. (01 de December de 2008). *Welcome*. Access at 18 de April de 2012, available at LLRP Toolkit: http://www.llrp.org/

O Brasil-ID. (31 Aug. 2009). Access at 18 August of 2012, available at Brasil-ID: http://www.brasil-id.org.br/sobre.asp

O impacto do caos nas ruas. (2008). Access at 28 April 2013, available at Veja.com: http://veja.abril.com.br/idade/exclusivo/transito/contexto1.html

Support Resources. (01 Jan. 2011). Access 10 de October de 2011, available at BeagleBone: http://beagleboard.org/support

The MVC application model. (s.d.). Acesso em 09 de 05 de 2013, available at Play Framework: http://www.playframework.com/documentation/1.0/main

Uckelmann, D., Harrison, M., & Michahelles, F. (2011). *Architecting the Internet of Things.* Berlin Heidelberg: Springer-Verlag.

Vanitchakornpong, K., Indra-Payoong, N., Sumalee, A., & Sriborrirux, W. (November de 2012). Performance Evaluation of a RFID-Enabled Real Time Bus Dispatching System: Case study of the Bangkok bus system. *ECTI TRANSACTIONS ON COMPUTER AND INFORMATION TECHNOLOGY*, pp. 144-155.

Wamba, S. F., Keating, B., Coltman, T., & Michael, K. (2009). *RFID Adoption Issues - Analysis of Oganizational Benefits and Risks.* Wollongong: Centre for Business Service Science - School of Information Systems and Technology.

Werner Von Braun. (2009). *Resumo Executivo dos Requisitos Técnicos.* Brasília: SINIAV.

Xiao, L., & Wang, Z. (2011). Internet of Things: a New Application for Intelligent Traffic Monitoring System. *Journal of Networks*, 887-894.

Zhou, H., Liu, B., & Wang, D. (2012). Design and Research of Urban Intelligent Transportation System Based on the Internet of Things. *IOT Workshop* (pp. 572-580). Berlin Heilderberg: Springer-Verlag.