Architecture for Mobile Application Integration on ERP with VRP for the Logistic Sector

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ABSTRACT : *ERP development has been an ongoing topic in Information System Industry for years now, being powered by cloud technology and mobile development rise on last years. While this is a generalized situation, some niche industries, like logistic sector ones, and specially hazard material logistics, has some requirements that makes them suitable to a deeper integration between the ERP layer and Mobile Application layer on their Information Systems Infrastructure. This is even a bigger concern when legal issues arise given the type of materials transported, needing VRP specialized solutions to fulfill those requirements. This paper presents a review of the technology and architecture for these specific systems, composed by ERP with VRP problems integrated solutions, and the integration process for an architecture used to communicate with mobile applications used on it. In addition, it is shown an example case of a developed system for a logistic company specialized in hazard materials. The system can compute routes and communicate the drivers the best plan in order to achieve a better management of the company resources and provide later data source for big data analysis about business operation to further optimization*

KEYWORDS –*Smartphones and tablets, Big Data, ERP, VRP, Systems Architecture*

I. INTRODUCTION

Our review of web technologies confirms evolution has been a constant from the beginning of the field, changing from CGI applications to SOA (Service Oriented Architecture), from simple HTML to RIA (Rich Internet Application) [10] SPA (Single Page Application) [16], from full page responses to REST services. This evolution has been going along with a strong and growing OSS (Open Source Software) community, which has impulse great projects, from infrastructure project as Apache, Tomcat, Jersey, Spring, etc., to high level projects as OSM (Open Street Maps, [20]), that compete with the biggest corporations and offers a great service.

1. Web Environment Technologies

From development point of view, the creation of frameworks like GWT (Google Web Toolkit), Smart GWT [25], GXT, ExtJS, MooTools, EmberJS, AngujarJS, etc, are a huge advance in user interface programming tools and capabilities. These frameworks drive the innovation at UI level from simple HTML pages to responsive and dynamic RIA SPA (like used at Twitter, Gmail). This kind of RIA SPA leads the user to behave as native applications, blurring the lines between web and local applications on perception level [21]. From these frameworks, SmartGWT and ExtJS are de best suited for an RIA SPA enterprise class web applications, as they have extremely powerful widgets that drives user interaction in a native application way. Smart GWT is especially useful as it can be integrated into a Java web project, and compiled as a whole, making easy to develop and debug its applications.

Other projects like Apache Struts 2, Jersey or Spring [35] in Java language, or Epiphany and Symfony2 in PHP, are examples of enterprise accepted frameworks developed under OSS environment. These frameworks are designed to make easy web development of big scale architecture solutions, using technologies as JSON for data interchange or paradigms like REST for service layer design. The use of JSON is getting

higher these days because of its simplicity and low memory footprint, which makes it ideal to be used on mobile devices with constrained resources.

At storage level there have been huge pushes on lasts years, mainly because of new NoSQL databases, and referred to web development it makes sense to look at document oriented storage solutions like MongoDB [17] or CouchDB [7]. Trying to replicate the way those works, there are traditional relational database solutions like PostgreSQL [22] adopting JSON as a native data type in their schemas, even allowing querying JSON data from SQL querys. As persistence solution, NoSQL databases document oriented has been integrated into solutions like Spring Data, and using Spring Data with Hibernate, while other solution like MyBatis [18] provides a lower level of abstraction and do not try to integrate NoSQL Solutions.

2. Mobile Application Development

2.1. Native Development

This has been the main development methods on the initial phase of mobile expansion. It uses technologies of the target platform for the application, and usually are oriented by the phone technology creator company. In this type of development, large platforms such as iOS or Android can be found, as well as platforms that have been falling into disuse such as Symbian or Windows phone, among others.

2.2. Web Development

Web development technologies has achieved a great expansion, both technologically and in its real-life use by the user base. Web solutions can be found on almost every sector and need. Its expansion has been so great, even new technologies has been developed to cover new use cases, like Progressive Web Applications, where a web page transforms to an application which can execute asynchronously tasks and has its own client database. These technologies have evolved to be able to "install" on devices, both computers and mobile devices, and act as native application like from user point of view.

2.3. Hybrid Development

Hybrid development goes an intermediate way between native and web development. In recent years it has had a great growth, due to the proliferation of basic technological solutions, such as Electron or React native, among others, which has allowed the integration of web development client technologies within compiled applications.
This has had the advantage of being able to port proven technologies from the web environment to the client environment, giving freedom in terms of the visual design of the applications, and finally it has allowed to have a broader base of developers, by being able to use the job market of web developers for the development of mobile applications.

3. Technologies Integration

Currently, the use of these technologies enables us to implement highly complex applications with low development time, such as advanced route optimization, delivery scheduling and logistics planning software. During the last decade, there has been acknowledged a tremendous change in enterprise-oriented business software where traditional products have gradually left their place to integrate, friendly, usable and efficient solutions that would rigorously deal with every single business aspect of each individual enterprise. These new applications, as a new generation of Web-based enterprise information systems, are gradually gaining ground, where the system structure is entirely modular, pluggable and separable and no component or module is obligatory for the application's operation. The VRP system presented in this article belongs to this category, as it is developed on SmartGWT, MyBatis and Spring Web-Development platform and possesses modular and flexible structure. Web-based techniques are less expensive, more efficient and lately have been the target of most development efforts. On the other hand, web-based solutions can easily interoperate with the whole supply chain entity.

Mobile applications, on the other hand, operates with different constraints on ERP environment: they act like sinks for real world data, so they provide planned operations for the users, and receives real world data. That data must be acquired, processed and integrated in an efficient way, while maintaining the whole information system healthy on data quality and operations, and representing an always changing world. As raw data generators, mobile application must be integrated with special focus on been able to adquire as much data as

possible, while giving a real time response to the user, given both kind of data users: the mobile application user and the ERP system user. Mobile applications take a higher role on ERP with VRP solutions, because they are primarily focused on location-based operations.

4. VRP

VRP systems allows to improve the process of designing the routes to follow by a heterogeneous fleet of trucks that transport a diverse number of products with different features (volume, cost, etc.), petrol and oil in this case, from n-depots to m-possible destinations (customers). While reviewing the VRP there are several variants [23], [12], [3], [1], [11], [14], [13], [23], [24], [4], [6], such as the periodic VRP in which customers are served in a period of time rather than a single day, the multiple depot VRP in which a company may have multiple depots to serve all its customers, VRP with pickup and delivery in which vehicles can both load and unload products at the customers, the VRP with time windows which defines a time interval within which the customer must be served, the stochastic VRP where one or more components of the problem are random, or the VRP with the choice of the heterogeneous fleet of vehicles. In order to solve the problem, an extensive group of techniques have been addressed, and can be classified into three categories: exact, heuristic and metaheuristic methods. All these techniques increase computer-time in order to obtain required optimization results and it is necessary to develop sophisticated programs in order to reduce the computation time. Here, a web-based system is constructed by using several metaheuristics algorithms. The system allows planning engineers to generate a near optimal vehicle assignment and routing plan based on daily shipping demands.

The improvements compared to the current situation, embrace the maximum occupancy of trucks, the total travelled distance, reduction of delivery times, minimization of distance travelled with minimal or no occupation of the truck, etc. The development of this system has been possible thanks to the use of SmartGWT, Spring, MyBatis, OSRM, Leaflet and Open Street Map technologies.

The vehicle routing problem (VRP) is one of the most studied among the combinatorial optimization problems, due both to its practical relevance and to its considerable difficulty. This problem is not a recent problem. It started with two classical problems in combinatorial optimization; the Traveling Salesman Problem (TSP) and the Vehicle Routing Problem (VRP). The basic problem, the TSP, consists of a departure point, to visit a set of customers with one single truck and to come back. It consists therefore to plan its tour by finding the sequence of customers with the lowest possible total cost. Historically, [9] is the first work that introduces TSP problem by proposing resolution's methods. The vehicle routing problem addresses the case where each customer has a given request. It consists in determining several tours that all start and end at the depot and where each customer is visited once by a single truck. The first work that addresses the VRP is [8]. The VRP generalizes the traveling salesman problem (TSP) and is much more difficult to solve than the TSP [14]. There are several variants to the VRP. These are formulated based on the nature of the transported goods, the quality of service required and the characteristics of the customers and the vehicles:

- CVRP ("Capacitated VRP"): *each vehicle has a limited capacity* [23].
- MDVRP ("Multi-Depot VRP"): *the seller uses several depots to supply customers* [12].
- PVRP ("Periodic VRP"): *orders can be taken only on certain days* [3].
- SDVRP ("Split Delivery VRP"): *customers can be served by different vehicles* [1], [11].
- SVRP ("Stochastic VRP"): *some values such as the number of customers, their demands, length of service or travel time are random* [15].
- VRPB ("VRP with Backhauls"): *customers can return the goods* [13], [23].
- VRPPD ("VRP with Pick-Up and Delivering"): *customers have the option to return some goods to depot* [24].
- VRPSF ("VRP with Satellite Facilities"): *vehicles can be supplied without returning to the central depot for other auxiliary route* [4].
- VRPTW ("VRP with Time Windows"): *each customer has to be served within a certain time window* [6].

A group of techniques have been addressed in order to solve the VPR problem, and can be classified into such as exact, heuristic and metaheuristic methods. The exact methods are efficient in problems up to 50 depots [2] due to the computational time constraints and classified them into three groups: direct tree search, dynamic programming, linear and integer programming. Furthermore, heuristic methods provide us with acceptable solutions obtained by a limited exploration of the search space. Within these methods we can find the construction methods, the insertion heuristic methods, elemental mapping, and so on. A review of these can be found in [19]. Finally, the metaheuristic techniques, developed in the late 90s, are characterized by performing a search procedure to find acceptable solutions by applying domain independent operators that modify intermediate solutions guided by the suitability of its objective function. Within these Neural Networks, Tabu Search, Genetic Algorithms or Ant Algorithms can be found, among others. A review of these methods can be seen in [5].

II. BASE STUDY CASE

A practical case is developed in a logistic operator of transportation in tank trucks specialized in dangerous cargoes, mainly in petrol products. This kind of activity have a high impact in the Spanish economy, at the same time, have quite strict security levels and rules. It worth to pointing out from the point of view of security as well as the economy, the proper management of the transport and distribution due to the extreme dangerousness of these type of products.

The system described aims to allow a suitable management of these works through the development of a solution for an environment using mobile devices inside of the trucks. This way is possible via calculations of optimal routes, to communicate in the real time the best ones for a specific service. All the developments have always considered the limitations that these types of products must respect to carry them on the roads.

1. ERP with VRP Architecture

The system designed for the development of this work has been based in a web architecture, specifically client-server, making use of a main server which contain the business logic and a relational database PostgreSQL as well as additional servers for other types of services such as route optimization or communication with the vehicles fleet of the logistic operator.

Those communications services are in use with a system already on duty, but they are limited by the operational capabilities of that system.

In order to be able to integrate other new systems, with other characteristics, without modifying the original ERP architecture, the ERP provides a component for real-time connection vehicle module, called “Hermes”. This module takes responsibility for outgoing and incoming communications with the mobile devices fleet.

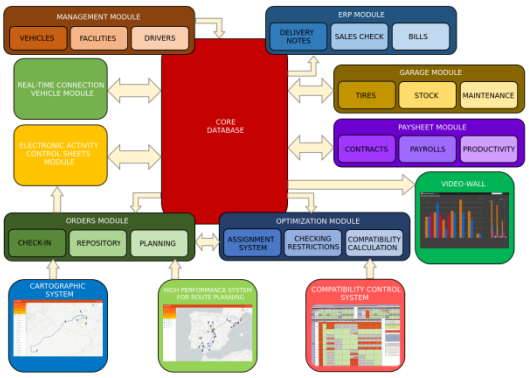

Figure 1. Diagram of the base study case.

The main part of the graphic interface of the system has been developed with SmartGWT, an extension of GWT which makes easier the codification in the client part using the programming language of JAVA, translating this code automatically into HTML and JavaScript. The Server side is implemented in Java 8, making use of different frameworks as Spring or persistance solutions as Mybatis. Services as route calculations and route optimizer use Matlab as well as OSRM libraries.

The communication between the client and the server is performed via AJAX requests, where the server provides a API REST. The data format follows the standard JSON, and also its extension GeoJSON for geographic data.

III. ARCHITECTURE PROPOSAL

Given the previous specification of the base study case, to be able to accommodate the needs of the CHRONOS system through Hermes component we’ve designed an agnostic architecture, shown on Figure 2.

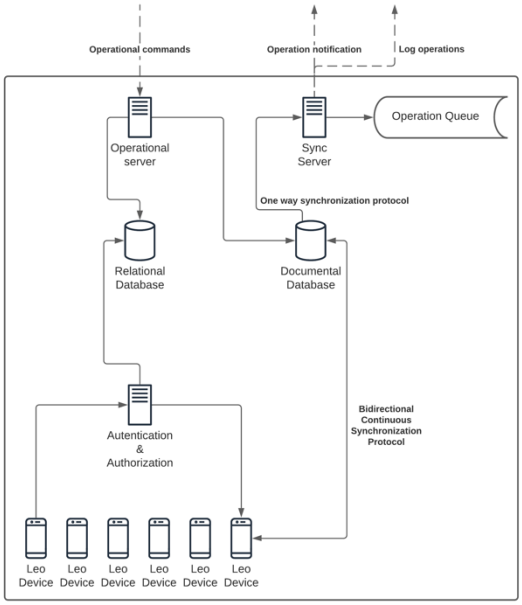

Figure 2 Diagram of the proposed architecture.

This architecture provides an adaptation layer to communicate the mobile application with the ERP. It is made up of several components:

- Operational Server: its responsibility is restricted to receiving operations from the ERP system. The operations received consist of the publication, update or withdrawal of work plans for mobile devices as the first objective. As a secondary objective, it is responsible for the authorization of devices in the system and the connection with users. It interacts with the relational database to keep track of the authentication and planning base data, as well as with the documentary database for the publication of work plans. Its proposed interface is a REST service, and its responses will be standard HTTP codes.
- Relational Database: its responsibility is to maintain a trace of all requested operation, also maintaining the authorization user database. This provides an external layer for the system access if required, as long as different user names and authorizations may be used.
- Authentication and Authorization Server: its responsibility is to provide the connection detail for user accessing the system once authentication has been made. A JWT system is proposed for this functionality.
- Leo Devices: these are the mobile application devices. Can be any mobile application as long as can use a JWT system and provide a bidirectional continuous synchronization protocol support. A react-native with local document database system is proposed.
- Documental Database: it's a document-oriented database where the elements of the plan to be executed by the users of the mobile application are created. The mobile application will have the job of issuing as many documents as needed notifying the changes in these elements. The concept of a document in the system includes all types of data structures that have their own coherence, as ACID. This allows to establish documents as representation of reality, or to collect events as own documents, going through all the different possibilities and combinations. Each of the generated documents will have a version number, generation date and generation point, so that it can be traced both from the application and in the real world where the documents were generated. The connection between the documents and the created plan is agnostic, so it can be adapted to different specific use cases. The use of documents based on JSON and base64 encoding is proposed to be able to have attached files in them, so that there is the flexibility of being able to process all types of input data to the system. One database per user is also proposed.
- Operational Queue: this component is oriented to be able to maintain a temporal-business related order of the documents received by the system: In a poorly connection environment, some documents may get synced out of order, so this queue is a multilevel queued based on business needs to be able to fill the gaps and keep track of all operations done by the mobile application user. A system with immediate persistence is proposed. This component represents the state' data of the proposed architecture.
- Sync Server: this component is responsible for maintaining the Operational Queue data and receives the updates for upcoming documents received by the Document Database. When, given the business logic implemented, a set of documents are complete and represent a new relevant fact, this fact has to be communicated to the ERP by the Sync Server. An HTTP REST service is proposed as data sink for the Sync Server to communicate to. Furthermore,

Sync Server will notify events at any given times to log onto the ERP system. This is a critical operation, as long as the Sync Server has access to all data received by the Documental Database, so it has a real representation of what has been generated and received from mobile applications, and this data can be processed through a Big Data platform to get insights of the operational perform of the whole Information System and detect as fast as it can possible dangerous deviations on operations.

IV. CONCLUSION

In this paper, a review of development technology on web, mobile applications has been made, with a review of VRP problems, in order to set a base use case to the work done.

We've presented a base study case for an ERP with VRP functions in need to evolve by integrating new mobile applications while maintaining its operations and functionality without changes.

We have proposed and presented an architecture to integrate mobile applications with ERP on the hazard material logistic framework, explaining their components, their responsibility, and proposing some technological solutions in order to make this architecture viable.

Some drawbacks on the architecture may arise given the weak connection environment that mobile communications may suffer: the architecture has a point that must be carefully watched in the synchronization protocol. While the one-way sync operations are easy to implement, the bidirectional continuous synchronization protocol may present some difficulties to be adopted. For this reason, we propose the use of a document approach, with documents as ACID data structure with version data integrated, in order to be able to control the weak connectivity problem for mobile devices on remote zones.

The novel approach taken on this architecture makes it easier to implement, while being flexible enough to accommodate to multiple business cases with technology already available, and capable of operating in environments with connectivity issues.

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