Towards a Hyperconnected Transportation Management System: Application to Blood Logistics

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Abstract. Internet of Things, connected devices, and other wireless sensors networks offer a number of new opportunities to manage transportation flows. This is particularly interesting for critical Supply Chains like Blood Supply Chains. In this research work, we investigate how such new technologies can enhance transportation system by better managing hazards and changes. By developing an event-driven decision support system, we demonstrate how a hyperconnected solution could change the way to design and control transportation routes. This decision support system will both inform users in real-time with relevant information and propose appropriate behaviors. This system will also allow improving the whole collaboration that exists between the shippers, the carriers and the customers. A dawning application to the Blood Logistics in France is developed to highlight potential benefits of such an approach.

Keywords: Hyperconnected · Transportation · Event-driven system · Decision support system · Blood logistics

1 Introduction and Research Objective

During the last decade the world has been drastically changed with the arrival of an important number of connected technologies and devices. *Internet-of-Things* [1] or *Hyperconnected Systems* [13] are some concrete means of this major change. This new approach is now essential in the wireless telecommunications domain [1]. The concept is based on the fact that *things*, *objects* or *devices* able to interact with each other are today everywhere [5] as far as legacy systems like ERP, APS, WMS. A common characteristic of those systems is their ability to emit in real-time a huge number of data. They are used nowadays in various domains like home, industry, leisure or marketing. The field of Supply Chain Management and Logistics is also continuously evolving regarding these new opportunities and a new type of projects appears. A lot of them focus on the use of new connected technologies to better support goods traceability [2, 7] or resources tracking [11, 17]. A great majority of existing research works on

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connected logistics are focusing on data collection and transmission, but very few are studying the use of these data to support concretely decisions. As pointed by [4], this is an important lack of current uses of *Internet of Things* and *Hyperconnected Systems*. This work indicated that one major room for improvement consists in developing systems able to transform all this raw and dynamic data into contextualized knowledge able to concretely support decisions. Our research aim is to contribute to this objective by proposing an innovative Transportation Management System (TMS) module able to use the knowledge produced by connected device and systems to support routing decisions in real-time. The objective is to help practitioners to be more agile in their decisions by better considering disruption, variability and hazard. Thanks to this agility, the blood transportation must be optimized which is necessary to face with the sensitiveness of blood components, the products diversity and the urgency of some needs.

The paper is divided into four sections. The first one discusses some key points on literature about this subject. The second one develops the proposed decision support system architecture. The third one presents the solution to enhance the agility capability while the fourth one describes an application case about the shipment of blood pouches to French hospitals.

2 Literature Review

2.1 Flexibility and Agility Needs

Naim et al. [10] affirm that to be competitive and sustainable, modern logistics must increase their flexibility capabilities. They described the flexibility through three logistics categories. First, there is the *routine logistics service* that limits flexibility requirements. In such case, the carrier is competing on price and time. He has to be able to gather road traffic information in order to adapt to route disruptions. Such a carrier should propose vehicles that are flexible or at least a fleet that is composed of different types of vehicles. Second, there is the *standard logistics service*. Here, the carrier proposes higher flexibility regarding the delivery and the mix. The collaboration is no longer adequate, the cooperation between carrier and shipper is required in order to ensure good coordination of their activities. In such a situation, stakeholders have to share information, plans and schedules. If the carrier cannot propose such level of collaboration, he has to develop collaboration with another one. This partnership should at least ensure coordination of activities. This should make larger the potential flexibility capacity offers. Finally, there is *customized logistics service* that offers a complete set of flexibility options. Complementary to delivery and mix, volume and product, external flexibility types are proposed. A close collaboration agreement between the shipper and the carrier is necessary as they have to closely work at a strategic, planning and execution level, and as they have also to share data and information at all levels. If the logistics offers becomes critical then, such a kind of collaboration can conduct to the creation of a single company (like a joint-venture for instance).

As delivery processes usually discuss the dynamic adjustments of vehicle [15], other academics emphasized on the agility requirements for Supply Chain and logistics. According to [4], agility can be considered as the ability to perform detection and adaptation to events (in a rapid and efficient manner). [6] show that existing decision support systems are often a critical factor in applying agility in the Supply Chain. The authors have demonstrated that to develop the Supply Chain agility, the speed and flexibility capabilities must be enhanced through dedicated decision support systems. Existing systems are generally relevant for managing the business processes of a given organization [6]. They concluded that existing decision support systems were designed for internal logistics management and they missed to support the logistics coordination capabilities that are particularly critical for the management of agility in Supply Chains. Even such systems have allowed enhancing the performance of some organizations; they are not sufficient to really support the agility in logistics business processes [6].

As a consequence, future developments in matter of logistics decision support systems will have to consider agility capabilities.

2.2 Transportation Management System

Transportation Management System (TMS) assists companies with moving goods from a point A to a point B within a high level of performance (efficiency, reliability, and cost effectiveness). Such a system generally includes route planning and optimization, load optimization, execution, freight audit and payment, yard management, advanced shipping, order visibility and carriers management. TMS is not new and the literature on this subject is rich. One major concern is the Vehicle Routing Problem (VRP) as it represents the heart of a TMS. VRP formulation is a generalization of the Traveling Salesman Problem (TSP). Since 60's, academics have continuously improved the way to optimize the VRP as demonstrated by [12]. In their review, they explain that the VRP is generally a graph composed of a set of routes for K identical vehicles based at a depot (initial node of the graph), such that each of the customers (nodes of the graph) is visited exactly once, while minimizing the routing costs. They indicate also that various variants have been developed in the literature during the last decades:

- Capacitated VRP: customers have demand for freight and vehicles have finite capacity;
- VRP with Time Windows: customers have to be visited during a specific time frame;
- VRP with Pick-up and Delivery: freight has to be shipped in given amounts at nodes;
- Heterogeneous fleet VRP: same than previously but with vehicles that have different capacities.

More recently new kind of TMS research projects appeared. Most of them have been tried to develop sustainable and smart transportation solutions able to solve the ecological and fuel shortage issues. Suzuki [14] for instance proposed a new truck-routing approach for reducing fuel consumption while Mehar et al. [9] presented a survey on sustainable TMS that aim to reduce ecological impacts. Mehar et al. [9] reviewed the existing solutions for green transportation and described also the future elements that have to be developed for limiting the ecological impact of transportation. But the major trend is about the use of mobile and connected technologies within TMS. Authors like [16] have proposed the implementation of a smart onboard *Global Position System*

(GPS)/General Packet Radio Service (GPRS) system to be implemented into vehicles for tracking their speed. This allows sending in a real time a message including the location and the speed, in case of traffic speed violation. Other research works have developed real time vehicles monitoring and smart TMS using smartphones [8]. This research project was composed of four parts: (1) web system (2) TMS real time tracking application (3) real time tracking application for customer (4) salesman supporting application. Last but not least, authors like Kim et al. [8] have proposed Smart TMS to better support the coordination between the logistics stakeholders. Actually, as the authors mentioned, carriers' environment is more and more complex and the stakeholders have to manage an increasingly number of data flow. This imposes new kinds of TMS that better manage information between partners, increase goods traceability, better monitor involved business processes, and support improving dynamic routing and security [8]. If there is a strong trend to improve the transmission and the gathering of data through different technologies connected to TMS, very few research works seem to have studied the concrete use of this huge amount of data.

We consequently hold that if TMS are quite mature, a room for improvement still exists regarding the development of dedicated decision support systems able to benefit of the extreme wealth that connected devices produce.

3 Proposal

3.1 Approach

Based on previous literature analysis, we have decided to develop an event-oriented platform able to help TMS users to enhance their agility capabilities. In this study, agility is considered as a way to adapt the dynamic of the situation and can be defined as follow [3]:

$$\text{Agility} = (\text{Detection} + \text{Adaption})^{*}\,\text{Reactivity} \tag{1}$$

- The detection is the disclosure of a situation gap that makes the ongoing business processes not relevant to the running situation,
- The adaptation is executed, when a gap occurs, to change the current business processes to make them better relevant to the context,
- The reactivity is a property that has to ensure that detection and adaptation are done in a real-time (as fast as possible).

From this definition, it appears that agility permits to detect if the ongoing transportation process meets the requirements of the existing situation, and to adjust those processes in case of need.

3.2 Agility Services

Our detection module is based on [3]. In this paper, the authors proposed a step able to disclose a gap based on 3 main phases (see Fig. 1):

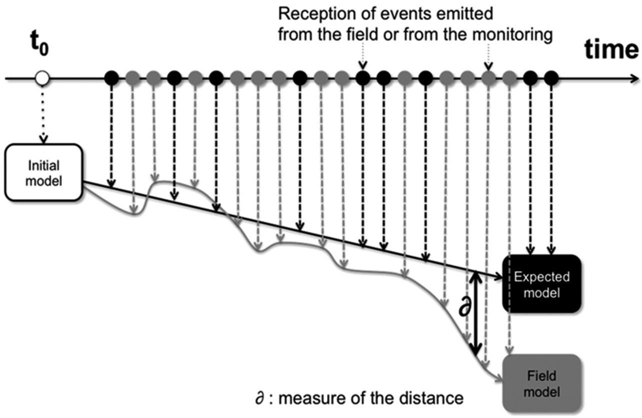

Fig. 1. Principles of divergence detection [3]

1. Establish a model of the situation in order to describe what should be the expected state when the processes will be applied and a model of the field to get a view of the current processes and real environment,
2. Identify potential gaps that might exist between the two models,
3. Calculate the distance that exists between the models to confirm or not the relevance of the ongoing business processes.

As mentioned earlier, agility needs both detection and adaptation. For the detection purpose, we propose to use connected devices and aggregate data they send continuously to create a contextualized knowledge and support concretely decisions. As for the adaptation purpose, we have developed a module that is able to measure the differences collected during the phase of detection. To reach such a goal, we define a set of business rules, which lists the different options that can be applied according to the nature of the detected difference. Then, the agility component is able to compare different options and select the best option(s) for adjustment to the TMS users. We have to remark here that the user always makes the final decision. The proposed solution is a decision support system that alerts on potential failures and suggests potential solutions. The system does not make automatic decisions instead of practitioners.

3.3 Architecture

The previous components have been implemented in a TMS platform that combines different technologies to manage collection, analysis and processing (decision-support) of events as real-time information. Figure 2 is a representation of this architecture that is divided into three parts: *Field*, *software architecture* and *monitoring*.

The *Field* aims at producing information about the situation without users' efforts. In order to be able to gather data about location and/or temperature of each product all the time, a possible solution consists in embedding sensors inside box and/or trucks (hyperconnection of containers). Indeed, these sensors are able to send data through

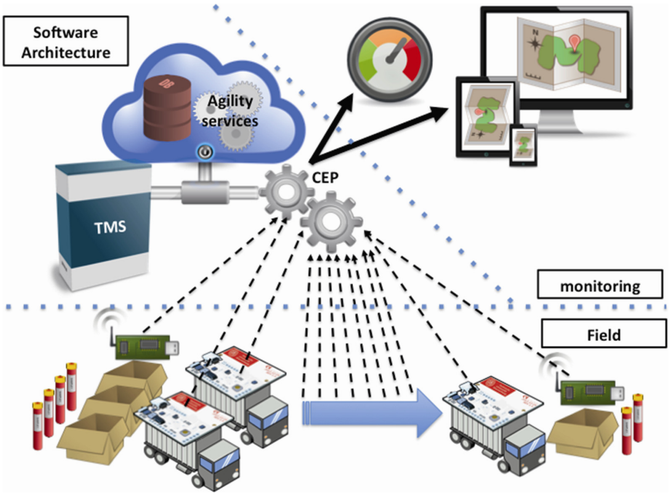

Fig. 2. Proposed hyperconnected TMS architecture.

several networks, as LTE, Bluetooth, ZigBee, Wifi or Sigfox, and thus it is possible to collect the information.

For now, TMS software is not able to collect and manage data producing by sensors. Therefore, the *software architecture* part provides a connected layer in charge of collecting, managing data from the *Field* and analyzing the situation thanks to an agility services describing in the previous section. This layer is based on Event Driven Architecture (EDA) and thus it is able to store, aggregate, forward events thanks to complex event processing (CEP) and database.

The last part aims at helping the user to *monitor* the situation thanks to Geographical Information System (GIS), indicators and result of the models comparison. Information visible on this layer is deduced from the TMS and the information from the *Field*.

4 Application Case

We develop in this section the case of French blood shipments to delivery centers. The French Blood Organization is split in 14 metropolitan regions. In each region, there are several places where people can donate their blood. In addition, the delivery centers are "blood supermarkets" where hospitals come to pick up the end products, derived from donors' blood, in order to treat patients. This donation and delivery places are often in the same site. In general, each region is made up of 20 to 30 sites.

The blood collected in donation centers have to be carried to the hub of the region where its components will be separated and filtered in order to make up end products. To ensure the use case accessibility, from now we only considerate the flow of end products (blood pouch) from the hub to the delivery centers.

In each region, daily rounds are planned to deliver the end products to the delivery centers. For instance, we consider that 5 sites, where the carrier has to deliver blood-derived product, constitute a round. Each site is around 40–80 km away from the other.

Currently, a truck leaves the hub with parcels that contain blood pouch for each site of its round. Because these products are very specific the French Blood Organization tries to deliver a broad range of products (blood pouch with different characteristics) to each site. However, it occurs often that a site needs as a matter of urgency a blood pouch that is not in its stock. In this case, the logistics department asks to one of its carriers it has a transportation contract with, for an urgent transport from the site (or the hub) that owned this blood pouch to the site that needs it.

Our idea is to be able to gather all the information linked with a round (sites, blood pouch ID, temperature, traffic jam, stock, etc.) to make it more efficient. The main goal is to be able to gather these data from all the sensors and databases to observe in real time the differences between the transportation process expected and the real one. Finally, we expect to save money and be able to manage with more efficiency the transportation activity. From this comparison, the proposed hyperconnected TMS will be able to suggest potential solutions. To permit this on going comparison and analysis, we have to define ad hoc business rules like:

– If a site of your round needs as a matter of urgency a product you will deliver it in more than 2 h, deliver it first to reduce this period.
– If there is an important traffic jam on the road between your site and the next one, deliver the third one first.
– If the temperature of the blood pouches in your truck is too high because of an unknown failure, go to the nearer site to stock these products.

Let us consider the following scenario as an illustrative example. In this scenario, there are one hub and five sites (Fig. 3). The carrier will drive 450 km and follow the following instructions:

– Start from the hub at 5 pm with the parcels prepared for the sites you are going to.
– Arriving at 5.20 pm to “Site 1”, deliver parcels for this site, leave at 5.30 pm.
– Arriving at 6.30 pm to “Site 2”, deliver parcels for this site, leave at 6.40 pm.
– Arriving at 7 pm to “Site 3”, deliver parcels for this site, leave at 7.10 pm.
– Arriving at 7.20 pm to “Site 4”, deliver parcels for this site, leave at 7.30 pm.

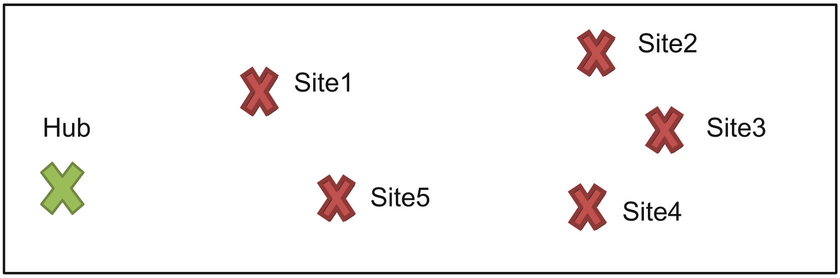

Fig. 3. Localization of the different delivery sites

– Arriving at 8.15 pm to “Site 5”, deliver parcels for this site, leave at 8.30 pm.
– Finish your round at 9 pm to the hub.

Currently, the carrier tries to be on time during the whole round and if he/she is getting late he/she cannot adapt anything to deliver on time the most urgent products.

With a TMS event driven system like the one we are developing, we should be able to manage a situation in which the planned schedule is no longer relevant. Through our proposal, the scenario will become:

– The carrier leaves the Hub at 5 pm. Leaving it, the system warn him/her that “Site 5” needs urgently a product he would deliver to it at 8.15 pm if nothing delays him/her. The system advice him to go to “Site 5” first, the carrier validates this proposal and the system warn “Site 1-2-3-4” of this delay.
– At 5.30 pm he/she arrives on “Site 5”, delivers the parcels for this site and leaves it at 5.45 pm. On his/her road to “Site 1” he/she receives a message. The “Site 1” will need a product that “Site 3” owns to treat a patient tomorrow. Because “Site 1” does not need its parcels quickly, the carrier changes his/her round and goes to the sites 2-3-4.
– Arriving to “Site 2” at 7.15 pm, he/she delivers the parcels and the system warns him/her that he/she will need twice time to go to “Site 3” than usual because of a road accident. The system suggests to adapt the round and to go to the “Site 4”. The carrier decides to follow the suggestion and goes to “Site 4” first.
– He/she leaves “Site 2” at 7.25 pm and arrives to “Site 4” at 7.55 pm.
– Then, he leaves at 8.05 pm and arrives to “Site 3” at 8.15 pm. He/she delivers the parcels for “Site 3”, takes the package for “Site 1” and leaves at 8.25 pm.
– Arriving at 9.35 pm at “Site 1” he/she delivers the parcels from the hub.
– He/she arrives at 10.05 pm to the hub.

We can notice that during this round the carrier does not follow the round initially planned and arrives with an hour of delay. Nevertheless, all real needs have been covered (and not the expected ones). Moreover, within the existing TMS system users would have needed to ask for urgent transports from the hub to “Site 5” and from “Site 3” to “Site 1” if the transportation company we are committed with exists in “Site 3”. Usually, this kind of exceptional round leaves from the hub because the company is located there. Finally, the carrier would have been delayed because of the road accident. In fact, even if he had known this problem by the radio, he would not have been allowed to change his round. Sometimes, “Site 3” knowing that the carrier goes to site “Site 4” next, give him parcels for “Site 4”. This short example shows how useful and economical this kind of event driven TMS is. Moreover, this ability to react in real time if anything unforeseen happen should permit to manage with more efficiency the Blood Supply Chain. It demonstrates how such a system could be very useful to manage critical logistics network like Blood Supply Chains.

5 Conclusions and Further Research

The research work presented in this paper is in its infancy. Nevertheless, it demonstrates how hyperconnection can be used to better manage transportation flows. This is particularly true for critical Supply Chains like Blood Supply Chains. In this project we are developing an event-driven TMS that will be able to both inform users in real–time with relevant information and suggest appropriate behaviors to adapt rounds to reality of the situation. A dawning application to the Blood Logistics in France is developed to highlight potential benefits of such an approach.

As this research work is just starting, numerous perspectives have to be exploited. The first one consists in finalizing the development in order to be able to experiment it on real application case. This should be done rapidly with the partnership of the French Blood Organization. The second one is about the connectivity of containers in which bloods products are transported. To do that some investigations with on-going research works on Physical Internet have been started. The third one is about the use of such innovative TMS to support collaboration between Supply Chain stakeholders.

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