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On the activeness of intelligent Physical Internet containers

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ABSTRACT

The aim of the innovative Physical Internet (PI) concept is to reverse the unsustainability situation existing in current logistic systems, to meet the increasingly demanding services required by the users and to increase the global logistic performance. In the PI approach, the goods are encapsulated in modularly dimensioned, reusable or recyclable, and smart containers, called PI-containers. This paper focuses on the informational context of such containers and more particularly on their associated activeness. This capability allows the PI-container to have an active role in achieving its mission and in the PI management and operation. After a presentation of the physical and informational aspects associated to PI-containers in hyperconnected logistics, a state-of-the-art review of the field of smart containers is provided. The limitations of actual solutions for fulfilling the informational requirements are highlighted. The notion of activeness is detailed and a descriptive framework is introduced. Finally, a grouping application of containers in a PI-hub is used to illustrate the proposed framework.

1. Introduction

Logistics activities are spread all over the world through a multitude of facilities, vehicles of various modes, and operators. Because of its ubiquitous nature, even in today's technological world, it is really difficult to follow logistics operations from end to end. Nowadays logistics deals only with passive (bar coded or passive RFID (Radio Frequency IDentification)) objects [1]. This situation limits the available information both in frequency and accuracy. For instance, in many supply chains the actual lead-time at the pallet or card box levels are not known. Usually, retailers do not even know the exact shipping location of inbound goods (often different from the manufacturing place). Despite the anticipated benefits, the cost of reading the high flow of data required to reach accurate and real-time information is still too high for widespread adoption. The reliance on active objects is a way to overcome this problem by autonomous communication not only to gather information but also to enable decision-making processes that will open new savings opportunities such as real-time routing to the market and accurate withdrawal.

Central to this paper, the Physical Internet (PI) has been introduced as an innovative concept contributing to reversing the unsustainability situation existing in current logistic systems, based on a metaphor of the Digital Internet [2]. By analogy with data packets, the goods are encapsulated in modularly dimensioned easy-to-interlock smart containers, called PI-containers, designed to efficiently flow in hyperconnected networks of logistics services. The ubiquitous usage of PI-containers is to make it possible for any logistics service provider to handle and store any company's products because it will not be handling and storing products per se. A PI-container not only protects goods but is also an intelligent object with logistics purpose. As outlined in [2], PI is to exploit as best as possible the capabilities of smart PI-containers connected to the Internet of Things, and of their embedded smart objects, for improving the performance perceived by the clients and the overall performance of logistics systems and of the Physical Internet as a whole. Through the increasing of its communicational and decisional capabilities, the PI-container can play an "active" role by itself in the PI management.

In this context, our paper introduces the notion of PI-container activeness and proposes a descriptive framework. This paper is organized as follows. Next, Section 2 is dedicated to presenting physical and informational requirements associated to the PI-containers and the corresponding hyperconnected logistics

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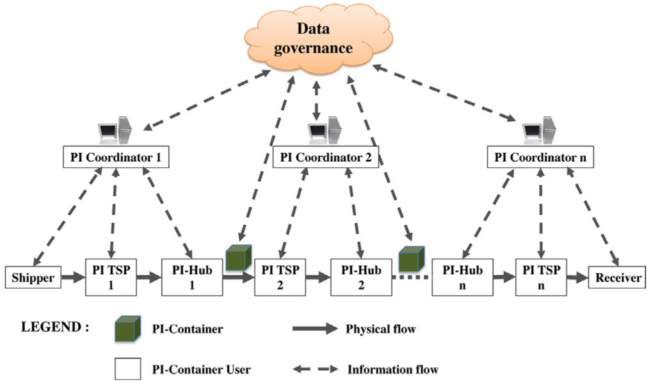

Fig. 1. Example of PI-container travel in the supply chain.

research projects. Section 3 reviews the state-of-the-art in the field of smart (intelligent) containers, highlighting limitations of actual solutions to fulfill the requirements of Section 2. Section 4 describes the notion of activeness associated to a PI-container and proposes a descriptive framework. In Section 5, a grouping application of containers in a PI-hub is used to validate the framework. Finally, Section 6 offers conclusive remarks and research avenues.

2. PI-container: past and current works

After a description of the central role of the PI-containers in the PI approach, the physical and informational aspects of PI-containers are successively presented and the current research projects are outlined.

2.1. The PI-container in the PI networks

To exhibit the role of the PI-container in the hyperconnected PI networks, Fig. 1 provides an example of PI-container travel. The main physical and informational flows are highlighted and users acting directly on the PI-container are categorized.

The container users can be separated into four classes. First are the shippers and receivers, here considered to be the clients. The second class includes the PI transport service providers (PI TSP) ensuring the transport activities. Third are the PI-hubs being used to transfer PI-containers from incoming PI-movers (e.g. PI TSP here) to outgoing PI-movers, as defined in [2,3], and the service providers in the PI-hubs, who ensure the receiving, sorting, dispatching and shipping services. The fourth class groups the PI coordinators, service providers in PI offering global informational services for interoperability and coordination of the shipments.

An efficient management of the PI networks requires linking the physical flow of PI-containers with the informational flow about them.

The physical and informational aspects relative to the PI-containers are detailed in the next sections.

2.2. Physical aspect of PI-containers and relevant project

In [2,4] are outlined key functional and physical specifications of PI-containers designed to enable hyperconnected logistics:

- Coming in various modular sizes, from cargo container sizes down to tiny sizes.
- Easy to handle, store, transport, seal, clench, interlock, load, unload, construct, dismantle, panel, compose and decompose.
- Made of environment friendly materials, with minimal off-service footprint.
- Minimizing packaging materials requirements through the enabling of fixture-based protection and stabilization of their embedded products.
- Coming in various usage-adapted structural grades.
- Having conditioning capabilities (e.g. temperature) as necessary.
- Sealable for security purposes.

In the recent field of PI, current projects aim to refine the PI-container concept and to fulfill these requirements. The first requirement is more particularly studied in [5] who investigate the exploitation of three modular categories of PI-containers, respectively the transport, handling and packaging levels, short-named T-containers, H-containers (or PI-boxes) and P-containers (or PI-packs). Modularity enables containers to better complement each other and therefore allows a better use of the means of transportation. Table 1 gives the main physical characteristics of these categories.

As depicted in Fig. 2, the relationships between categories exploit two mechanisms:

– *Encapsulation*: The three categories can be successively encapsulated one within the other.
– *Composition*: In a same category, the PI-containers can be composed and interlocked to build “composite” PI-containers and allow easier handling or transport, sharing the same standard type of interfacing devices.

The European MODULUSHCA (MODUlar Logistics Units in Shared Co-modAl networks) project [6] focuses on the design of handling PI-containers relying in modular construction and attachment between them. The attachment property allows building a composite H-container that will be handled as a bigger one, thus enabling handling productivity and less individual picking [5]. Prototypes of H-containers have been introduced by [6,7].

Table 1
Physical characteristics of the PI-containers categories.

Type of PI-containers	Dimensions	Functionalities
Transport container	External dimensions on the order of 1.2 m, 2.4 m, 3.6 m, 4.8 m, 6 m or 12 m. Sections with width and height both being either 1.2 m and 2.4 m.	Designed to be easily carried, to endure harsh external conditions and to be stackable as usual maritime shipping containers.
Handling container	External modular dimensions along the *X*, *Y* and *Z* axes fit within 1.2 m T-container, at 100%, 50%, 40%, 30%, 20% and 10% sizes. Stackable up to at least 2.4 m high.	Designed to be easily handled by PI-handlers (conveying systems, lifts. . .) and to resist rough handling conditions in the different nodes of the PI networks.
Handling container	Modularly fitting within H-containers as these fit within T-containers, with same range of dimensions.	Designed to contain directly the goods, replacing typical custom packaging in protecting and marketing them. Thin and light, designed to be easy to insert, extract and stack.