Physical Internet: Literature review and research opportunities

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Abstract. With an increasingly rich and personalized product offering, the digitalization of the commercial relationship and the opening of world borders, commercial transactions have never been this important. And so are the requirements in terms of time and availability that logistics and supply chains should fulfill. These latters still support the growth of the economic exchanges but struggle to find a disruptive model capable of meeting more requirements with sustainable economic, environmental and social approaches. Several initiatives are under consideration, including the Physical Internet, which offers an abstract, generic and global framework for managing the logistics chain of physical objects. In this article, we review the literature of the Physical Internet following the qualitative content analysis method. We found that although the number of contributions is limited, the contribution grows at a rate of 25% every year on average. We analyzed the contributions after categorizing them to find that the governance (management and community) of the Physical Internet from a global perspective is not covered enough by the current literature which can be an opportunity for future research.

Keywords: Physical Internet, Literature review, Qualitative content analysis

1. Introduction
The technological evolution and particularly moving everything to its digital representation is transforming the way people act and behave. The commerce is not an exception where the physical contact between the buyer and the seller or its products is no longer necessary. People can move from one product to another and even change stores with a few clicks instead of minutes or hours. They can do it without leaving their place instead of walking hundreds of meters. In such a new context, there seem to be no physical nor temporal constraints. This adds more constraints to current supply chains mainly because customers may believe that they can physically get the goods they are buying with just a few clicks. In fact, they don't know whether the goods are stored in the neighborhood or are located on another continent but still expect them to be delivered as quickly as possible. This challenge is what today's and future logistics and supply chains must handle.

The Council of Supply Chain Management Professionals defines the logistics [1] as “The process of planning, implementing, and controlling procedures for the efficient and effective transportation and
storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements”. If we can replace the goods by the data in this definition we will end up with data logistics which is continuously evolving with the Digital Internet.

In fact, in the digital world, user experience is continuously enhanced. Users can share big amounts of data easily (images, videos, etc.). Data exchanges are increasingly growing at a very fast rate but paradoxically the costs are dropping. The new infrastructures support even more volumes and further enhance service quality. So, we could ask ourselves if the data logistics is that powerful, why not to be inspired by its underlying principles to disrupt goods logistics? How similar are the digital exchanges compared to physical exchanges? And if these two areas are similar, what approach to reproduce the success of the digital exchanges onto the physical ones?

2. The Physical Internet

The introductory questions suggest a concept that physical objects can be moved with as much simplicity, security, and efficiency as digital data. Such a concept appealed to the authors of a logistics study published in a special edition of The Economist [2] in June 2006 under the title "Physical Internet". The authors suggest the word implicitly by describing the similarity between a goods warehouses and Internet routers, physical packets, and information packets, and logistic networks compared to computer networks. Thus the word "Physical Internet" (abbreviated PI or π [3]) was used for the first time.

This new term interested researchers [4] who have found in the physical Internet not only a metaphor but a new angle of view that could consolidate the various singular initiatives to improve the performance of supply chains. Thus was born the concept of the physical Internet as it will be presented in this article with the publication of the 1st "Manifesto for a Physical Internet" by B. Montreuil in 2009 [5]. Then, B. Montreuil gives a first version of the vision of the Physical Internet [6] by describing its characteristics as a response to the inefficiency and the unsustainability of current logistics. Flowing the analogy with the Digital Internet, the Physical Internet was then defined as “an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces, and protocols. It is a perpetually evolving system driven by technological, infrastructural and business innovation.” [7].

This work catalyzed and federated researches aimed at optimizing supply chains around the Physical Internet. By addressing the three issues (economic, environmental and social), the paradigm was adopted by the European Union in 2013, which is ALICE (Alliance for Logistics Innovation through Collaboration) with the ambition to fully implement the Physical Internet in Europe by 2050 [8]. In the same way, several academic institutions have launched research branches to meet the needs of their government and/or industry [5].

Although the Physical Internet concept comes from the Digital Internet, they both remain related. The recent digital and data management concepts can be very useful to the Physical Internet and even be concrete enablers for its real implementation. Some technologies are particularly very tied to the Physical Internet such as IoT [9], big data [10], AI [11] and blockchain [12].

3. Review methodology

The main goal of this work is to give an up to date overview of the research publications about the Physical Internet and to “summarize the state of the art” [13] in that subject. Following the guidelines from Seuring and Gold [14] which are based on Mayring [15] works, we used the qualitative content analysis method with its four-steps illustrated in Figure 1.
Figure 1. Four steps of the qualitative content analysis.

3.1. Data Collection
The Physical Internet is a recent topic. In order to give the best picture possible about the Physical Internet, we used different databases: ScienceDirect, IEEE, and ResearchGate. To select the most relevant publications up to 2018, we looked for “Physical Internet” as an exact expression in titles, keywords, and abstracts (Table 1). The publications were then post-processed to eliminate non-relevant work and especially where “Physical Internet” means the physical infrastructure of the Internet.

Table 1. Search Expressions and post processing.

| Database     | Search Expression                                                                 | Post Processing                      | Publications removed |
|--------------|----------------------------------------------------------------------------------|--------------------------------------|---------------------|
| ScienceDirect| “Physical Internet”                                                               |                                      | 5                   |
| IEEE         | ("Publication Title":"Physical Internet")                                      | Title, keywords, abstract, screening | 3                   |
|              | OR ("Author Keywords":"Physical Internet")                                     |                                      |                     |
|              | OR ("Publication Title":"Physical Internet")                                   |                                      |                     |
|              | OR ("Document Title":"Physical Internet")                                      |                                      |                     |
| ResearchGate | “Physical Internet”                                                               |                                      | 4                   |

3.2. Data Analysis
Using the above criteria, we found 96 publications of different types: conference papers, journal articles, books, magazines, etc. From the overall publications, 62 were published in the last 3 years (2016-2018) which represents 65% of the publications with a progress average of 25% every year as illustrated in Figure 2. ResearchGate has the most important share with 64% of the publications followed by ScienceDirect with 21% and IEEE with 15% as illustrated in Figure 3. Most contributions are published as articles (54%) then as conference papers (35%) as illustrated in Table 2.

As to authors, 141 contributors were found. The top 10 authors are cited 87 times which is 31% of the overall citations. Eric Ballot is the most cited author (21 times) followed by Shenle Pan (16 times) and Benoit Montreuil (15 times).

Through the research process, we noticed that the publications on the Physical Internet are very limited. We found only four literature reviews. In the first [4], the authors focus on the theoretical foundation of the Physical Internet. The second [5], is a special issue to identify critical challenges and to stimulate research contribution. The authors of the third review [16] focus on the adoption of the Physical Internet. The last one [17] is a systematic literature review of the scientific literature around the Physical Internet.
With respect to the qualitative content analysis, the categorization process and the findings are explained in the next section.

4. Results and discussion
The purpose of this section is to highlight the least covered areas of the Physical Internet in order to give researchers the opportunity to contribute with original works. Starting from the digital Internet as a basic metaphor, we have identified some categories to qualitatively analyze publications and frame their evaluation.

4.1. Data Categorization
The literature about the Internet reveals four different aspects that make its history [18]: the technical/technological evolution, the operations and management, the community and the commercialization. The Internet disrupted the way people and systems communicate. To reach this goal or at least approach it on the physical world, we can start with what made the success of the Internet. In this journey, we want to check whether the Physical Internet is following the same pattern or a different one. We used the four aspects behind the success of the Internet as our main categories. Then we analyzed the contributions and classified them to the category that best matches their content (Table 3).
Table 3. Physical Internet publication categories.

| Category                                | Number of publications |
|-----------------------------------------|------------------------|
| Technical/technological evolution       | 92                     |
| Commercialization                       | 2                      |
| Total                                   | 94                     |

4.2. Data Evaluation
The final analysis shows that almost all contributions are related to the Physical Internet itself. They give answers to how PI should be implemented with models, simulations and use cases.

Only two contributions cover commercialization and business model. Unfortunately, no contribution specially addresses how to manage the Physical Internet from a worldwide perspective and how to accelerate and engage further contributions, how to manage and build a community that will support and guarantee the Physical Internet evolution.

The success of the Digital Internet is due among others to the community of its users and the way it was governed through time [18]. To complete the analogy and if we target a wide adoption of the Physical Internet, we think that the identification of the governance and the potential business models of this disruptive concept are required. These topics are not covered enough by the current literature which opens opportunities for contribution. Future research may particularly answer the following questions:

- The relationship between the Digital and the Physical Internet is only a metaphor or a deep analogy? We think that the relationship between the Digital and the Physical Internet is not clearly defined. From our perspective, they are analog and parallel [19]. Thus, we can infer most of the knowledge from the Digital to the Physical Internet with few adaptations.

- How to develop a community of scientists, professionals, industrials and users that will contribute to the implementation, management, and improvement of the Physical Internet? Recent collaborative models such as crowdsourcing and open sourcing show that the bigger the community and the more heterogeneous it is, the quicker is the progress and the adoption. We believe that the adoption of the Physical Internet and its development can be further enabled and accelerated by demystifying and popularizing its underlying concepts to wider community.

- What can be the disruptive business models for the Physical Internet? Is it possible to transpose SaaS, PaaS and IaaS concepts to the supply chain? Companies have different needs and maturity levels. Big ones want more control with less investment and small ones struggle to manage their logistic service. We think that the Physical Internet can serve different kinds of needs thanks to the anonymization and the optimization in every layer. We can, for example, offer infrastructure services like logistics centers rental or platform services like cross-docking operations.

5. Conclusion
In this article, we reviewed the literature around the Physical Internet following the qualitative content analysis method. We categorized the results using the historical aspects (technical/technological, management, community and commercialization) behind the success of the Digital Internet to find similarities and suggest new research contributions.

The findings show that the Physical Internet is still a local initiative and that a worldwide management of its operations is not covered by the literature. We also found that the current contributions do not work on building a large community through popularizing of the fundamental concepts of the Physical Internet. Thus, we suggest some research perspectives by first inferring the knowledge from the Digital Internet and its history. Then, work on a worldwide vision of the Physical Internet.
Internet through a governance system and a wider community. And last, looking for disruptive and affordable business models inspired by the digital ones and enabled by new advancements in automation, autonomous navigation and IoT.

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