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FUNCTIONAL REQUIREMENTS FOR PRODUCTION INTERNET (Ψ)

Abstract. Production Internet as an eco-system built on public infrastructure of Web-services would go beyond the traditional setups of industrial cooperation, as well as existing peer-to-peer services for economic exchanges, like e-sharing, e-tailing or crowd-funding. This paper discusses functional setups of Production Internet. Throughout the practice review and foresight research, the functional needs, requirements and benefits have been identified. The validation of functional specification was performed using a prototype multi-robot setting.

Keywords: Production Internet, Production Ecosystems, Collaborative Networks, Cloud Manufacturing, Smart Manufacturing, Web-services

WYMOGI FUNKCJONALNE DLA INTERNETU PRODUKCYJNEGO (Ψ)

Streszczenie. Internet Produkcyjny (Ψ) jako ekosystem bazujący na wykorzystaniu publicznej infrastruktury usług sieciowych, ma wykroczyć poza ramy tradycyjnych form współpracy w przemyśle opartych na usługach peer-to-peer, takich jak: e-tailing, e-sharing czy crowd-funding. W pracy przedstawiono wyniki analizy wymogów funkcjonalnych dla Internetu Produkcyjnego. Poprzez przegląd teorii i praktyki, poparty badaniami foresight, zidentyfikowano potrzeby i korzyści oraz typy użytkowników. Walidację koncepcji przeprowadzono przy zastosowaniu opracowanego prototypowego środowiska wielorobotowego.

Słowa kluczowe: Internet Produkcyjny, ekosystemy produkcyjne, produkcja w chmurze, sieci współpracy, inteligentne wytwarzanie, usługi internetowe

1. Introduction

The globalized industries experience increasing networking and openness. The major drivers of this megatrend are globalization and technology developments. The first eco-systemic platforms built on Internet capabilities, like Facebook or Alibaba, exhibit significant and widespread impacts, and cause meaningful changes in social life and economics. The main streams of Web-based eco-systemic developments are coined together as the Seven Internets [12]. Some of them like the Logistics Internet (π) [7] and Production Internet (Ψ) [12], are still rather ideations than a reality. The latter one, which is expected to provide a new stimulus to the globalized industries, is subjected to investigation in this paper.

Production Internet is expected to go beyond the existing forms of peer-to-peer Web-services, which support the economic exchange, like e-tailing, crowd-funding or e-sharing. By aligning capacities and capabilities of collaborating parties, it should also go beyond the limits of dominant patterns of industrial organizations, i.e. markets, supply chains and partnerships. The two breaking innovations of Production Internet are through consideration of structured products and services which can enable novel forms of collaboration, and automation of matching demands and provisions. The emergence of Production Internet is conditioned by particular technologies. The two most essential are Web services and semantic technologies [2]. The other are: cloud computing, multi-agent/robot systems, knowledge-based and cognitive technologies, smart appliances, and Service Oriented Architectures (SOA).

This paper focuses on functional development of the Production Internet, which is assumed as an ecosystem employing Web services to support cooperation of clients, manufacturers, forwarders and vendors along their operations. The core functionalities of Production Internet are built around spatiotemporal qualitative and quantitative alignment of offered products, manufacturing and logistical resources, with the demand flows.

The paper is organized as follows. The next section reviews the state-of-art, theory base of industrial cooperation, ICT developments, and existing Internet platforms and ecosystems that can be recognized as heralds of Production Internet. Section 3 presents results of foresight research concerning the emergence of Production Internet, considering probable ways of its evolution. Section 4 analyzes applicability and benefits of the Production Internet. Section 5 proposes functional specification for initial developments. Section 6 presents prototype which was elaborated to validate the proposed approach, and enable the experimental research. Section 7 summarizes the paper, and reflects on possible future research and development.

2. State-of-Art and Gaps

The organization of industrial cooperation follows a variety of patters, ranging from traditional market supply to novel forms of virtual collaboration. The theoretical foundations for adoption of ICT to support the economic exchange are given by the following theories:

- The resource based view centers on the offering of company’s capacities and capabilities as the source of competitive advantage [1]. In this view ICT can support organizational performance, especially in reference to utilization of resources.

- Transaction costs theory focuses on the governance structures of economic exchange [14]. Herein ICT is recognized as a mean to reduce the transaction costs of managing cooperation, including searching, bidding, and monitoring activities.
- The relational view seeks competitive advantage in inter-organizational relationships [3]. Therefore the strategic role of ICT can be viewed as the facilitator or enabler for particular enhancements, with regard to the inter-organizational competitive advantage.
- The dynamic view recognizes the role of organization’s capabilities to rapidly and smoothly adapt, reconfigure, integrate, and extend its resources and abilities, in response to the changing needs and requirements [13]. Similarly, the ICT can be viewed as an enabler and facilitator to the dynamic capabilities.
- The resource dependence theory focuses on the uncertainty in utilization of resources belonging to other firms [8]. Herein the strategic role of ICT is to aid the ability of an organization to control and limit the dependence on others resources.

The ICT, and especially the Web-based systems and ecosystems, and in the near future also the cognitive solutions, offer an outstanding potential for improvements to the interacting industries, which can bring about substantial benefits suggested by all of the theories. This question is further investigated in the subsequent sections.

The existing ICT developments are represented by wide range of technologies and systems to aid the cooperation of industrial companies. They are [4, 5, 9, 11]: ERP1, ERP2, EAI, ERP adapters, SCM, DRP, CRM, WMS, TMS, ECR, CPFR, EDI and I-EDI, mobile & tracking technologies (M-CRM, RFID, PDA), Web services, Semantic Web, grid computing, cloud manufacturing, cloud-ERP, knowledge-based systems, ontologies, smart agents.

If the existing systemic solutions offer the capacity to consider structured products and services, it is by proprietary systems used within rigid boundaries of cooperation. Centrally maintained data structures are used in such cases to represent products or services . Otherwise the coordination is operated on the transaction basis, like the B2B, B2C, O2O, and so on. The existing systems typically use classic triggering mechanisms to coordinate the inter-organizational cooperation, like replenishment or pull flows. The offerings of products, services and resources to the external parties are always given as exact items (or catalogues). Qualitative characterization of goods, services and resources is not available. Although the recent concept of cloud manufacturing hypothetically provides a significant potential to support the development of Production Internet, it still remains rather a research topic, being discussed at high level, mostly form architectural and technological point of view (e.g. [4]).

Some existing Web services, which mostly emerge in China and USA, anticipate arise of Production Internet and can be considered as its heralds. All of them represent the megatrend coined as sharing or access economy, which concerns such economic arrangements in which participants open and mutualize access to resources, products and services, rather than exploiting advantages of ownership. The most representative examples of the whole variety of heralds of Production Internet are as follows: Alibaba/Taobao as ecosystem for clients, manufactures, sellers and forwarders; CreditEase as the platform for peer-to-peer lending and microfinance; Groupon as demand bulking service; Covisint as auctioning platform to purchase standardized products; Zuora as demand subscription service; NetSuite OneWorld as cloud service for multi-company management of resources; Kickstarter crowdfunding platform as demand, supplies and funding amalgamation service; Cybernauts as the business integration platform to support start-ups, alliances, joint ventures, ad hoc ventures, etc., to integrate entrepreneurs and venture micro-capital. Although the listed platforms exhibit a reach volume of networking and integration services, all of them do not go beyond the limits of peer economy, and follow the integration pattern of online market places.

3. Foresight Research

This section reviews the foresight research of Production Internet. The expert panel involved: technology providers (Huawei, SAP), Web-services (Taobao, Cybernauts, Alo7, Haozhuanye), consultancy (Accenture), ICT focused venture capital business (KnowledgeHub), and professional societies (Crowdfunding World Championship Council, China). The semi-structured interviewing was run in a face-to-face mode. A set of questions was provided in advance, then being used to lead the interviews, and supplemented by other direct, indirect, and ad hoc questions. The later brainstorming sessions were operated via Skype. All interviews were precisely documented, and in most cases recorded. The questions provided in advance have been focused around the following topics: (1) New inter-organizational solutions, in terms of services/processes, structures, architectures, coordination principles, patterns of demand, patterns of service and resource offerings and provisions; (2) Distributed, heterarchical, and herd control of operations; (3) Other new functionalities; (4) Knowledge and cognitive supports, semantic networking, knowledge management; (5) Trust and credibility management; (6) Possible patterns of deployment and evolution; (7) Benefits.

The major finding and conclusions from the performed research can be briefly summarized as follows:

1. Principally Production Internet should focus on manufacturing, stock-keeping and forwarding, selling services, and the related coordination. Ultimately it should be supplemented by a variety of support services, like: (1) trust, reliability, and credibility management; (2) bidding; searching, discovery, and matching of various offerings and demands, both in qualitative and quantitative way, and considering spatiotemporal aspects; (3) tracking demand, work and material flows, payments; (5) management of legal responsibility; (6) confidentiality management; (7) funding;

2. Followingly, final clients, manufacturers, and forwarders can be recognized as the main actors along the beginning development of Production Internet;
3. The generic model of bills of materials/processes based coordination, using relational databases cannot be effective in large scale environments, like the Production Internet; novel forms of formulating demand should be attempted, e.g. by going beyond the ‘due date-due quantity’ concept, avoiding scheduling based coordination, etc.;
4. Distributed and heterarchical modes and structures of coordination should be considered;
5. Robotized decision making, considering the cognitive abilities, should be exploited to avoid the shortcomings of human-made decision (e.g. due to the asymmetric perception of risk, herd behavior, learning and forgetting asymmetries, and so on); similar supports, like the business intelligence systems, Big Data, smart appliances et al. should be also;
6. Recognizing regional and overall characteristics of ecosystems, like states or phase transitions (e.g. in reference to changing loads or variability characteristics), to facilitate and modify the ongoing coordination of flows;
7. Interacting with the existing legacy systems should be also considered.

The findings from the foresight research suggest a particular evolutionary pattern for development of the production Internet, which is exhibited below in Fig. 1.

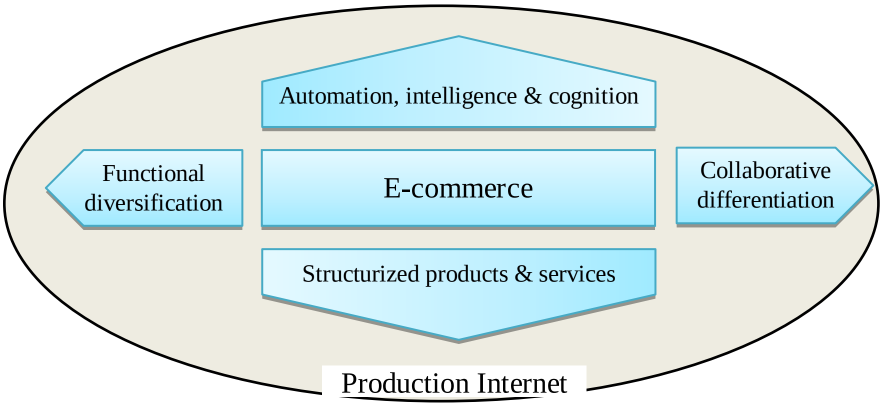

Fig. 1. Evolution towards the Production Internet
Source: Own development.

It is suggested that the E-commerce ecosystems, like the Alibaba/Aliexpress, should be viewed as the conceptual basis for initial developments of Production Internet, which have to start from a breaking innovation – consideration of products and manufacturing services as structured items. This grounding development shall be followed in a twofold way by functional diversification, i.e. by adding consecutive functions, and collaborative diversification, i.e. by adding new actors of cooperation, as well as consecutive forms of economic exchange. The crowning of Production Internet will be throughout a progressive enrichment by automation, artificial intelligence, including the autonomous cognition. Possibly bio- or eco-mimetic emergent intelligence to support the homeostasis of the production ecosystems can be innovated at the end.

Other results of this research are presented or considered in the further sections.

4. Applicability and Benefits

The successful deployment of Production Internet will rely on the adaption to the needs and requirements of its users, the importance of offered benefits, and the environmental and contextual fit. This subsection addresses applicability of Production Internet.

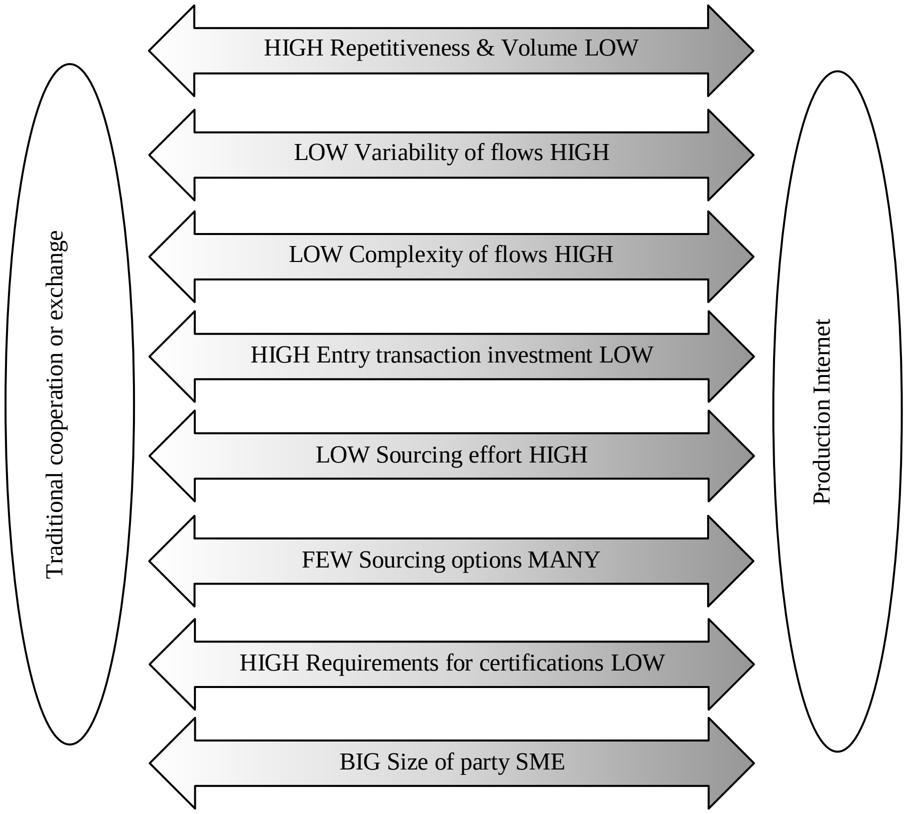

Fig. 2. Factors for successful dissemination of Production Internet
Source: Own development.

The foresight research introduced in the preceding section has identified a range of success factors for the extensive dissemination of Production Internet. The leverage between traditional cooperation and ICT support, and the Production Internet, depends on various aspects and characteristics of cooperation, sectorial conditioning, and particular characteristics of the interacting parties. All important factors identified are presented in Fig. 2, by visualizing the opposing directions of pros and contras. It is suggested that the Production Internet will be primarily attractive to those SMEs, for whom transaction costs economics is critical. Easy sourcing and small transactions costs are assessed as major conditions for dissemination. Lack of requirements limiting cooperation, like requested certifications, provides an additional advantage. Other factors relate to certain aspects of interaction between collaborating parties, like the low repetitiveness and intensity flows, as well as the high complexity and variability of interactions. The expert panel also identified important advantages expected along dissemination of Production Internet. Apart of benefits to the participating parties, which interestingly correspond with all the competition related theories of industrial collaboration, the overall impacts on economy, society and environment, should be also appreciated. Among them the following have been assessed as the most important:

- Increased visibility of offerings; therefore improved utilization of owned resources;
- Improved operational performance (lead times, inventory turnover, productivity, flexibility); increased capital turnover; overcame economies of scale;
- Easier and faster identification of requested or offered products and services, like the contractors; hence, reduced transaction costs;
- More extensive exploration of vendors; hence reduced dependence on others' resources;
- Intensified provision from relationship assets, in particular due better exploitation of synergistic effects of complementary and distinctive resources;
- Improved changeability and reduced need for changeability;
- Improved performance of whole economy (including capital turnover; wastefulness, etc.);
- Reduced powers driving towards spatial concentration of economic activities; hence, improved opportunities for localized and distributed economic activities;
- Increased welfare; more inclusive and sustainable economy;
- Improved eco-friendliness of industries; reduced waste, emissions and pollution.

The above picture of effects provides a sound argument in favor of dissemination of Production Internet. As the technological barrier in terms of ICT does not actually exist, it is only a matter of time before the appearance of first Production Internet platform. The results of foresight research suggest that due to several advantages China is the most probable birthplace of such novel ecosystem.

5. Functional Specifications

The foresight research enabled identification of functionalities to be offered by the first generation solutions of the Production Internet. Considering the welcome impact of this innovation, and taking into account the probable roadmap towards first developments, the following functionalities have been selected as the primary targets:

1. Offering of structured products (from stock or manufactured) and manufacturing services,
2. Offering of resources (processing, warehousing, forwarding);
3. Credibility assessment; credibility based conditioning;

4. Bidding, auctioning, discounting,;
5. Qualitative, quantitative and spatiotemporal matching of demands and provisions;
6. Operational coordination of material, work and information flows (based firstly on pull flows, VMI, and limited patterns of pull flows);
7. Product and process data management;
8. Demand (orders, subscriptions, schedules) and orders processing; orders tracking;
9. Claims and returns management;
10. Payments management; limited credit services.

The first expected users of Production Internet interacting along performance of the above listed functions will be clients and bidders (individuals and companies).

6. Experimental Development

This section reports a prototype development of Production Internet, mainly to enable its simulation. The secondary purpose was to validate conceptual setting of Production Internet. This environment could be used in the future for experimental research and educational use. The development is supported by two key ICT technologies: multi-agent systems [6] and ontology engineering [11]. The multi-agent environment provides capacity for mimicking Web services and Web-based interactions [6]. Additionally it provides a setting for the Service-Oriented Architectures and cloud-based infrastructures [6]. It was also considered as the initial technology to automate coordination activities. The prototype implementation was made using GAIA based conceptualization, and JADE, WADE and WOLF toolkits. Using the prognostic approach, reference functional architecture was elaborated [Fig. 3], which is organized into four layers. All of them presume multi-agent/robot setting to manage services. All robots are equipped with own operational ontologies.

The brokerage & coordination layer includes robots aligning demands and offerings, by spatiotemporal matching of products, resources, services and demands. The transformational approach is applied to explode and aggregate demands, and then services [6]. Brokering robots match demands, resources and services, while balancing robots leverage the traffic of flows by considering utilization and synchronization. The bottom layer interfaces processes, resources and users. The propositioning robots handle offerings, while transaction supervisory robots manage load of resources, fulfillment of internal orders, receiving, and forwarding. As yet, top two layers have not been implemented. The homeostasis layer takes aggregate view of operations and focuses on overall balance of loads and flows. It concerns blockings and jams caused by temporal overloads of capacities and reduced supplies. Alternative streaming of flows can be advised to the balancing robots in lower layer. The role of this layer is similar to aggregate planning and follows the idea of adaptive control. The layer of evolution considers self-adoption of ecosystem including autonomous cognition. New behavioral patterns can be self-learned with regard to the observed changes, e.g. in terms of variability, mix of services. The change can be implemented by advising new rules to robots operating in lower layers. Although these capabilities look futuristic, the available cognitive technologies enable such implementations, at least in certain areas, like widespreading of newly learned rules of allocating demands and services into knowledge of balancing and streaming robots

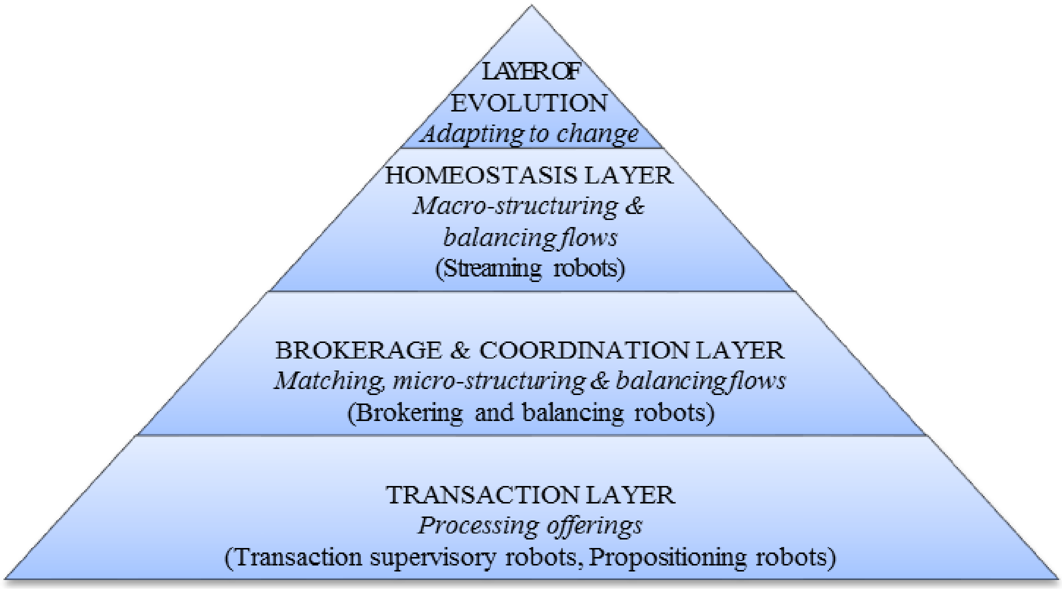

Fig. 3. Prototype setup of Production Internet - generic layered structure (only internal domain)
Source: Own development.

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The prototype development employs a limited scope of functionalities and does not pay attention to the scalability. This kind of approach can be justified by the focus of the initial implementation on functionalities, and with this regard - discovery of particular issues that can be faced in the future along the further extension of the Production Internet.

7. Summary and Further Work

This paper investigates possible functional arrangements of Production Internet. Throughout reflection on the state-of-art, supplemented by a foresight research, the needs and benefits identified and composed into use-cases. Later on a validation was performed using a prototype multi-robot setting. The investigated eco-systemic solution of Production Internet should significantly limit the shortcomings of existing economical institutions, especially by: improved operational performance; increased sharing and utilization of resources, improved transaction costs economics, finally improved economic performance of economic exchange.

The future research should explore other functionalities and collaborative settings. The deployment and of cognitive abilities is another important extension Production Internet. Also the scalability provides a challenge to the further work.

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