Research on Collaborative Processes in Non-Hierarchical Manufacturing Networks

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Abstract. Collaborative networks research has increased over the last years due to the advantages experienced by the enterprises that establish collaboration. In this paper, a set of relevant collaborative processes are identified in the literature and analysed considering their specific application in non-hierarchical manufacturing networks (NHN). Besides, collaboration within networked partners is enhanced through designing a roadmap to deal with the migration path towards collaborative processes establishment. Currently, the research aim is focused on modelling the network and the collaborative processes, established within the partners, through a mathematical model that identifies the collaboration objects. In this context, experts will be able to promote the establishment of collaboration, analyse the processes performed within a network and consider their redesign/design towards collaboration. The model would identify the objects of collaboration, in order to be analysed and thus serve as a tool to improve the enterprises' performance and, consequently, the network performance.

Keywords: collaborative processes, non-hierarchical networks, collaborative networks, SMEs.

1   Introduction

The interest increase on collaborative processes establishment, within partners of the same network, has resulted in an increment on the emergence of the number of network topologies [1], [2]. Amongst all the network topologies this research is focused on collaborative non-hierarchical manufacturing networks (NHN) [3]. Unlike hierarchical networks (HN), based on centralised approaches of decision making in which one partner possesses all the power, NHN are characterised by the establishment of collaborative processes with decentralised decision making models (DDM). The establishment of collaborative DDM in NHN implies that all the network partners are autonomous; all decisional independent units are collaboratively involved in the management of the network processes and integrated with different degrees of collaboration. Involved partners equally enjoy power sharing and status, and no individual partner leads the network [4].

For enterprises whose nature does not imply a hierarchy in the network structure, conforming decentralised and collaborative structures, that is NHN, provide important

benefits [5]. These benefits are led to improve the network competitiveness, innovation, partners' adaptability, customers' satisfaction and inefficient processes elimination [6]. DDM, in which the NHN are based on, improves each network node commitment as regards to the overall goal of the network while improving communication, collaboration and flows among nodes. Furthermore, NHN, as equally considers all network partners, helps SMEs to position in the global market [7]. NHN are characterised by long term partnerships with close collaboration. Accordingly, collaborative DDM changes the way how processes are executed in a network, implying an evolution towards collaboration, in which the exchanges of information are to be done in an interoperable way and the business processes are jointly performed. Thus, this paper particularly focuses on collaborative NHN.

1.1   Motivation and Research Question Formulation: Collaborative Processes in Non-Hierarchical Networks (NHN)

Research in collaborative non-hierarchical manufacturing networks is motivated, on the one hand, by the call funded by the European Commission, "FP7-NMP-2008-SMALL-2" (Activity code *NMP-2008-3.3-1: Supply chain integration and real-time decision making in non-hierarchical manufacturing networks*) [8]. On the other hand, the Intelligent Manufacturing Systems initiative (iNet-IMS) has encouraged to (i) analyse the needs that arise from relationships between SMEs belonging to NHN, (ii) analyse the technology innovation trends to support DDM, (iii) analyse standards for information exchange to support collaborative processes and (iv) define a framework for collaboration in NHN [7]. Moreover, the growing interest of enterprises on establishing collaboration has led to study the establishment of collaborative processes. Therefore, the development of a Collaborative Framework (proposing models, guidelines and tools) to handle with the barriers SMEs can encounter when establish collaborative processes, is considered the research line followed by the thesis. Taking into account the above said, the research questions are hereafter raised:

(i)   Identify, through the literature review, relevant collaborative processes that networked SMEs perform [6].

(ii)   Analyse the collaborative processes treatment in order to determine how the approaches provided in the literature deal with the NHN characteristics and therefore can be applied to support the establishment of collaborative processes within NHN partners [3], [6].

(iii) Recognise the non-covered processes, as regards the solutions that do not treat the collaborative process in specific contexts of collaborative and decentralised NHN [3], [9].

(iv)   Provide solutions in the NHN context to fill the literature gaps of non-covered collaborative processes. In order to fill these gaps, research on new approaches to model collaboration is to be considered from the NHN perspective [10], [11].

(v)   Build a Collaborative Framework containing a set of models (M), guidelines (G) and tools (T) to support SMEs on their participation in collaborative processes within decentralised NHN structures. The Collaborative Framework consists of a set of building blocks characterised by the type of collaborative process and the type of solutions (M, G and T) to cope with the process [6].

(vi) Develop a roadmap to support SMEs on the migration path from non-collaborative NHN towards collaborative NHN [12].

(vii) Model the collaborative network, NHN, and the objects identified to deal with the collaboration and formally conceptualise the collaborative processes performed. The formal model will serve researchers as a tool to analyse the degree of collaboration set up within groups of networked partners.

Once identified the research questions, the paper is devoted to identify the relationship between the research developed within the paper and the *Collective Awareness Systems* (section 2). Besides, the literature review results as regards collaborative processes are shown (section 3). The research contribution and innovation is proposed (section 4) and research results are discussed (section 5). Finally, conclusions and future research lines are identified (section 6).

2 Relationship to Collective Awareness Systems

Collective Awareness Platforms for Sustainability and Social Innovation (CAPS) are ICT systems leveraging the emerging "network effect" by combining open online social media, distributed knowledge creation and data from real environments in order to create awareness of problems and possible solutions requesting collective efforts enabling new forms of social innovation [13].

In collaborative NHN contexts CAPS can be adopted to support distributed enterprises to collaboratively act. CAPS can give the clue to achieve a situation in which independent partners establish collaborative processes and handle with the encountered barriers in a sustainable way. The decentralised decision making perspective of NHN requires greater exchanges of knowledge and information, and commitment of all companies without losing their authority in decision making. In the light of this, CAPS would provide a proper platform to support (i) the partners' information access in real-time and easily understandable, (ii) the consideration of both SMEs and the network, (iii) the access to environmental models and simulations to deal with collaboration and (iv) the collaboration promotion within the partners.

The main aim proposed in this paper is to achieve sustainable NHN, characterised by DDM through establishing sustainable collaborative processes. For these reasons, CAPS in NHN are to be considered to integrate all decisional units, perform greater exchanges of information, share responsibilities, involve all the SMEs in the network decision-making, tackle problems jointly and take into account the objectives of all the partners by equally considering all the networked nodes.

3 Literature Review: Collaborative Processes

The literature review carried out collects the diverse knowledge on the research arena of collaborative processes, both in HN and NHN contexts. The works analysed so far (1981-2012) reveal the existence of an extensive literature concerning collaborative processes. The literature review was carried out considering the most relevant

processes to establish collaboration; the processes were reviewed considering the solution's approaches used to deal with them: models, guidelines and tools.

Afterwards, an analysis was completed in order to identify into which extent the treatment given in the literature was appropriate to be applied from the NHN perspective; that is the extent into which the approaches to support collaborative processes can be employed in decentralised and collaborative networks. Three classification criterion are used: (i) *NHN* when most of the contributions to deal with the collaborative processes are designed from the NHN perspective (ii) *HN → NHN* when most of the contributions are designed form the HN perspective but can be adapted to the collaborative and decentralised features that characterise the NHN and (iii) *HN* when most of the contributions in the literature are designed for HN.

The processes identified are classified according to the three decision making levels, strategic, tactical and operational and according to the solutions degree of application (NHN, HN→NHN and HN) (table 1).

Conforming to the classification criteria, the existence of some processes that are not specifically treated form the NHN perspective are identified.

The main conclusion deduced from the literature review is led to consider that there are a set of processes that still do not have a complete treatment in the literature due to the approaches to support the collaborative processes are not provided form the NHN perspective. These processes are identified considering those belonging to the group of *HN* and *HN→NHN* (see table 1).

Table 1. Collaborative Processes and Degree of Application [3], [6]

		STRATEGIC			TACTICAL			OPERATIONAL	
Collaborative Processes	(1)	Network Design	HN→NHN	(1)	Forecast Demand	NHN	(1)	Scheduling	HN→NHN
	(2)	Decision System Design	NHN	(2)	Operational Planning	HN→NHN	(2)	OPP	NHN
	(3)	Partners Selection	HN→NHN	(3)	Replenishment	HN→NHN	(3)	Lotsizing Negotiation	HN
	(4)	Strategy Alignment	HN	(4)	Performance Management	NHN	(4)	Inventory Management.	HN→NHN
	(5)	Partners Coordination and Integration	HN→NHN	(5)	Knowledge Management.	HN→NHN	(5)	Information Exchange Management	NHN
	(6)	Product Design	HN→NHN	(6)	Uncertainty Management.	HN	(6)	Process Connection	HN→NHN
	(7)	PMS Design	NHN	(7)	Negotiation Contracts among partners	HN→NHN	(7)	Interoperability	NHN
	(8)	Coordination Mechanisms Design	HN→NHN	(8)	Share costs/profits	HN			
				(9)	Coordination Mechanisms Management	HN→NHN			

4   Research Contribution and Innovation in Collaborative Non-Hierarchical Manufacturing Networks

According to the literature reviewed, a set of non-covered processes are identified as regards the collaborative NHN perspective. Therefore, the main aim is to design

solutions to fill the gaps in those processes whose degrees of application are classified as *HN* and *HN➔NHN*. The processes classified with the **HN** degree of application are the *strategy alignment*, *uncertainty management*, *share costs/profits* and *lotsizing negotiation*. An example is considered with a solution proposal for the *share costs/profits* process. The methodology, *Share Profits in Non-Hierarchical Networks* (SP-NHN), is designed to ensure equitable sharing among networked partners to foster collaborative and trust behaviours and deal with the gap of collaboratively *share costs/profits* [10]. The research also considers the processes classified in **HN➔NHN**, in order to adapt the solutions provided in the literature and procure suitable solutions from the NHN perspective. An example can be found with the *operational planning* process, considered a complex activity in collaborative NHN due to the agreements and standardised processes demanded. In the light of this, a solution is adapted, from the literature considering the novel *Supply Chain Agent-based modelling Methodology that supports a Collaborative Planning Approach* (SCAMM-CPA), in order to handle with the problems associated when the *operational planning* is performed in NHN under a collaborative perspective [11].

Taking into account the literature reviewed and admitting that many factors and conditions may cause threats, specifically in SMEs, when establishing collaborative processes [3, 9] in decentralised NHN; a roadmap, to support the new SMEs challenges, is provided. The importance on collaboration within the networks under study encourages the development a roadmap to deal with the evolution from non-collaborative scenarios towards the establishment of collaborative processes among the SMEs decided to participate in decentralised and collaborative NHN. The roadmap, *NHNmap*, consists of a set of ten phases structured into four main areas (i) collaboration establishment, (ii) performance evaluation, (iii) solutions' proposal to overcome possible barriers appearing when collaborative processes are established, and (iv) information and technology systems to efficiently manage the decentralised decision making models that characterise the NHN [12].

An additional research contribution is identified with the modelling of collaborative networked processes, as well as modelling the NHN. This research line is the early stages of development.

The modelling research line is motivated due to, currently, the models proposed in the literature are based on individually model specific collaborative processes, such as interoperability, collaborative product development or knowledge management, amongst others. Therefore, a gap is found to provide a general only model that could be valid for all the identified collaborative processes. Thus, regardless the process to be modelled an only model could be used through identifying different objects that take part in each of the collaborative process. In the light of this, a new research line is proposed to design a collaborative model and identify the objects participating in the establishment of collaborative partnerships. The model is to be generally designed in order to be used by the vast majority of the collaborative processes previously defined in the literature reviewed [6]. The model is to be developed to support researchers on the formal conceptualisation of the collaborative processes, giving them an insight of (i) how to analyse the processes and measure the collaboration (ii) how to design a collaborative process, if this does not already exist or (iii) how to redesign a process, if this has not been already executed from a collaborative

perspective, in order to globally improve the network performance and individually improve the enterprises' performance. An example can be encountered in [4], that models the network, the relations established within the networked partners, and the links between them to determine where the partners' transactions lead. A model is proposed to allow researchers to identify the power degree of each networked partner and therefore determine the power distribution. Once the network, the partners and the partners' relations are modelled, *Markov Chains* are used to compute the power distribution. Modelling the power and therefore the relationships of the network nodes allows to better consider the networked partners' relationships and obtain more sustainable and balanced networks.

5   Discussion of Results and Critical View

Taking into account the results obtained from the literature reviewed, it is evidenced that a high percentage of the approaches developed in the collaboration research field are mostly designed from the HN perspective, so do not have a full application on collaborative processes established by SMEs belonging to NHN. The lower complexity on HN treatment makes them more studied. Contrarily, research in collaborative NHN environments is less widespread due to researchers have to deal with companies that could be part of several production networks at the same time; what motivates the study of these networks. In the light of this, the research focuses on the creation and management of non-hierarchical manufacturing networks and the proposal of supporting approaches for SMEs to establish collaborative processes in networks characterised by DDM, in order to simultaneously deal with both the enterprises' objectives the and the global objective defined for the network.

Considering the outcomes from the literature review and the results based on the iNet-IMS initiative, relevant collaborative processes and barriers associated to SMEs, when participating in NHN, are identified. A Collaborative Framework is built as a set of solutions classified into models, guidelines and tools to cope with the SMEs requirements when participating in collaborative NHN. The research developed provides, researchers and practitioners, an approach to handle with the changes needed to be performed by the SMEs in order to efficiently achieve the desired future state of establishing collaborative processes in NHN, and, therefore, get the benefits derived from the collaboration.

Furthermore, the design of a collaborative model allows to (i) model the network and the collaborative processes, (ii) quantitatively analyse the collaborative relationships, (iii) determine how the network system is, AS-IS and (iv) propose a collection of tools and guidelines to cope with collaborative barriers so as to improve the establishment of collaborative processes within the involved parts of the NHN. A quantitative analysis on the established collaborative processes is needed to identify the most relevant processes performed and those that are lagging behind but indeed are important to be performed. The quantification will determine how the system is and how important is to make improvements throughout the network.

Dealing with the NHN and the barriers associated with the collaborative processes establishment is a laborious task due to the added difficulty to individually consider each of the companies with its objectives, strategies and particularities. Moreover the existence of conflicting objectives appearing, due to companies belong to more than one network, are to be taken into account. This research work is a step forward in the study of real networks consisting of autonomous SMEs and deals with the next generation of manufacturing enterprises embedded in global environments characterised by multi-lateral collaborations.

6   Conclusions and Further Work

Research in NHN has been launched only few years ago therefore there is a long way of work to cover in the future. This research is focused on identifying those processes that can be collaboratively established within a NHN and modelling the NHN in order have a current view on the processes performed in a NHN, with the main aim to improve the partners collaboration through solutions procurement. The Collaborative Framework for NHN will give researchers a tool to, once identified the barriers when collaborative processes are established, overcome the appearing weakness through the application of models, guidelines and tools provided.

The high interest on the topic under research and the wide variety on the approaches to deal with collaboration, leads the research contributions to: (i) summarise the existing knowledge regarding the establishment of collaborative processes within networks, specifically in NHN; (ii) provide a roadmap to overcome the possible barriers appearing when SMEs decide to participate in collaborative NHN and (iii) design a formal model defining the collaboration objects to allow researchers to specifically model the collaborative processes and the network.

Future research lines are led to provide solutions amongst all the processes that are not treated form the NHN perspective; for processes with **HN** degree of application solutions will be designed; for processes with **HN➔NHN** degrees of application existent solutions in HN would be adapted to be applied in NHN contexts. The results obtained so far reveal the need of providing a collaborative framework to cope with those processes that are treated in the literature without considering NHN features. The work developed so far has provided a set of solutions to overcome the collaborative processes form the NHN perspective [10], [11], [12]. This research begins a series of solution proposals to build a Collaborative Framework for NHN, designing new models, guidelines and tools to support the establishment of collaborative processes in the networks under study. Future work is led to complete table 1 and achieve, for all the processes, **NHN** degrees of application.

The standardisation of the collaborative processes established within the networked SMEs is to be done in order to consider the information exchange systems in an interoperable way and the negotiation mechanisms to regulate the collaboration within the network.

Considering the aforementioned, future work is led to (i) identify or design models guidelines and tools to deal with collaborative processes in NHN contexts, (ii) consolidate collaborative processes across a network through Information Systems

and Technologies (SI / IT), (iii) promote collaboration through the implementation of the roadmap, (iv) validate the proposed Collaborative Framework through its application to various industrial pilots and (v) design a formal model for collaboration and implement it in real networks.

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