Swarm-based coordination of business networks: An approach for collaborative value creation of innovative goods and services

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Abstract

The evolution of collaborative behavior within the World Wide Web (WWW) offers a high potential for new business models. Today, this potential cannot be exploited in all aspects, because the basic principles and mechanisms behind the behavior are still unclear. In this paper we describe a basic approach for the coordination of the production of new and adequate goods and services within a business network based on collaborative behavior following the rules of natural swarms. The approach offers possibilities to build new business models for service integrators while exploiting new and innovative kinds of customer behavior. To analyze and explain the mechanisms of the approach as well as its effects on performance, i.e., productivity, we present a cause-effect-model which serves as a basis for the next research step.

1. Introduction

In the context of Web 2.0 or Second Life, business networks face new challenges to coordinate the production of goods and services in an efficient way. Changes in the digital environment and new phenomena, enabled by these changes, have to be considered. Examples for currently discussed topics are the integration of the customer into the production process [15], the use of customer creativity, or the utilization of collective intelligence [4]. In recent years also the term “swarm intelligence” was discussed as an approach to gain benefits from the changes in the WWW [11]. The discussed approaches are mainly targeted on the demand side. As a consequence, the focus lies on the customer and the digital market [11][12]. Examples of business models using these approaches are Threadless (www.threadless.com), Marketocracy (www.marketocracy.com) or InnoCentive (www.innocentive.com). On the supply side the use of swarm intelligence or the deployment of mechanisms of collective intelligence focuses on optimization problems. Areas, which are mainly targeted, are the production process or logistic methods, respectively [16]. However, these approaches can also be beneficial for the process of bundling and producing innovative and adequate goods and services within a business network. With the rise of virtual organizations basic mechanism of swarm intelligence, like self-organization, were discussed in literature. However, today, true self-organization cannot be found in practice [10]. Mostly intermediaries act as central coordinators. To implement a more efficient coordination of the production of new and adequate goods and services within a business network, the consideration of natural mechanism of self-organization can be helpful. The adaptation of swarm behavior of social insects can be one valid approach to implement efficient self-organizing business networks. The obvious gap between the theoretical discussion and the implementation in practice can be closed by mixing both approaches, i.e., to establish the role of an intermediary and at the same time allow for self-organization. Performance is a crucial success factor of a business network. Terms like networkability describe the internal and external capability that a company needs to collaborate with other companies within the network and to build an effective and an efficient business network [20]. To have a much more efficient network, the networkability has to be as high as possible. Today, research discusses how the networkability can be optimized (e.g. [1]). A swarm-based coordination of business networks can help to foster the networkability and the performance of the business network whose potential has not yet fully been exploited. As an effect of the approach presented here, more efficient business networks can emerge.

Business networks are a major characteristic of the internet economy. The actors in a network can be divided into service integrators, service providers, shared service providers, and exclusive service providers [3]. In the following, the role of the service integrator and its potential for creating value within the
Business networks are divided into different types. For example, we can find virtual organizations, project networks or strategic networks [14]. In general, a business network is an organizational structure to gain competitive advantages. Therefore, independent organizations work together in a cooperative and non-competitive way [27]. During the strong growth of the WWW, the term virtual organization was coined. A virtual organization can be described as a temporary business network. In this network, companies collaborate to exploit an upcoming market opportunity or to meet a special customer demand. The companies within a virtual organization are legally and economically independent and mostly have complementary core competencies. As a rule, there is no centralized coordinator but the participating companies act as one company towards the customer. An additional characteristic is the predominant use of modern communication and information technology [7]. In literature virtual organizations were conjured as organizations of the future [29]. In reality this kind of organization has not yet become a widespread model of doing business. But in fact virtual organizations offer a basis for new concepts of digital markets and business models. Therefore, we build upon this organizational model as a basis for our approach.

2.1. Intermediaries as coordinators within business networks

Typically, strategic networks or project networks are characterized by one centralized company with leader functions within the business network. In contrast to these network types, virtual organizations use polycentric coordination mechanisms. The focus on the core competencies of the included companies is an advantage of this type of networks. However, the polycentric coordination mechanism is difficult to implement in practice. As a consequence, virtual organizations started to implement a centralized coordinator [10]. They chose one company of the network which had to adopt special know how for its coordination tasks and had to focus on the network management. Miles and Snow [18] discussed this phenomenon early and named the centralized company “broker”. Many other authors discussed the role of these intermediaries and divided them into different categories. Gerpott and Boehm [10] analyzed miscellaneous types of intermediaries and differentiated between “entrepreneur”, “middleman”, and “opportunist”. The “entrepreneur” combines core competencies of companies with his own competencies to offer products and services in the market. The “middleman” combines core competencies of
companies triggered by customer needs. If one single company cannot fulfill the demand, the “middleman” combines companies with the required competencies. The focus is on the combination or rather coordination of the suppliers and moreover the management of the whole configuration process by the “middleman”. The “opportunist” acts as an intermediary by identifying market opportunities and offering special solutions for these opportunities by building business networks for specific problems. Many other definitions of intermediaries can be found in connection with digital markets. Selz [22] uses the term “value web broker”. A value web broker is a classical coordinator of supply and demand who combines different products and services to new bundles. Moreover, a “value web broker” acts as an infomediary who analyzes customer needs to give this information to other companies. Baumoel and Winter [3] use the term “service integrator”. This kind of intermediary integrates miscellaneous products and services to offer an integrated solution for customer processes. The “service integrator” is the interface between customers on the one side and suppliers on the other side.

2.2. Self-organization of the production process

Coordination and development of virtual organizations are based on self-organization which is a result of the interaction and communication among the individual companies without having a central coordinator [10]. However, the intermediaries described before can be found in many existing business networks or virtual organizations, respectively. But if one company in a virtual organization has to fulfill the role of an intermediary, the original definition which bases upon self-organization cannot be applied anymore. In fact, it becomes a new type of business network with a centralized or hierarchical coordinator. Gerpott and Boehm [10] therefore discuss self-organization in virtual organizations as a theoretical approach that cannot be found in practice. The mechanism of self-organization in business networks is not widely discussed in literature. Only a few authors take a closer look at this kind of organization mechanism (e.g. [30]). The intermediary is discussed as an appropriate part of virtual organizations (e.g. [6]). A resolution to the obvious gap between the theoretical discussion and the implementation in practice can be found in a mix of both approaches, i.e., to establish the role of an intermediary and at the same time allow for self-organization.

3. Swarm-based production of goods and services

The transfer of research approaches to other research areas or the development of new approaches based on natural phenomena can result in new solutions for existing problems. One example is the self-organization in social insects, so called swarm behavior, which is used in areas of research like biology, robotics or operations research (e.g. [4] [28]). Based on natural swarms, these areas of research aim at the development of new solutions with respect to the behavior of insects, fish, or birds. The transfer of this natural paradigm started in the nineties and is still a popular research topic [16]. In recent years the transfer to economic questions was explored more and more in the context of swarm mechanisms and swarm behavior [12] [19].

Many companies today aim at using the collective intelligence of their customers. To do this, they integrate the customer into their production processes. Examples are Spreadshirt (www.spreadshirt.net) or 121Time (www.121time.com), where the customer can design products. Moreover, some business models are completely based on the participation or collaboration of a community. Mahalo (www.mahalo.com) employs professional editors and the user of the search engine to edit the search indices. StumbleUpon (www.stumbleupon.com) bases upon a combination of opinions to give recommendations of websites to other websurfers. All these examples are often associated with swarm behavior. But a full transfer of the natural swarm mechanism has not yet been successfully made. Intermediaries in digital markets primarily act as coordinators of demand and supply. Customers’ demand triggers the intermediary to coordinate the combination of adequate products and services by service providers. Although it would be a considerable potential for value creation, the intermediaries mostly do not consider the willingness of customers to contribute in a holistic way. Many web 2.0 services are based upon the customer’s collaboration. More and more people become part of web-based social networks or communities and share their knowledge in shopping networks or wiki projects like wikipedia (www.wikipedia.org). Next to the role of a market coordinator, intermediaries have to expand their role. They have to learn, how the collaboration of the customers can be used to gain knowledge from the customers ideas and innovations to build more adequate bundles of products and services [2]. With these information about the customers’ needs the intermediary can support the business network to provide optimized and innovative solutions. At the
same time the production of goods and services within the business network has to be optimized by the intermediary. This step can also be based upon the additional information the intermediary gains. Similar to the approach of Hagel and Armstrong [13] as regards changing markets in online communities, the supply side exchanges information with the demand side. Customers in web-based social networks, in online communities, or in initiated artificial customer swarms take on the role of the suppliers. The intermediary acts as a consumer. The development of a swarm based business network could be one valid approach to deal with the changing market and to optimize the production of goods and services in business networks. The intermediary as the interface between customers on the one side and suppliers on the other side is now responsible for the initialization, the analysis and the interpretation of an actively initiated customer swarm. In addition, the intermediary has to coordinate the production of goods and services within the network of providers in an effective way. In the following, the approach for a swarm-based coordination of business networks is described.

3.1. Swarms and swarm behavior

The self-organizing behavior of social insects or birds, and fish became generally known as swarm behavior. In literature there are different terms in use to describe the results of this behavior. Examples are swarm intelligence (e.g. [4]) or swarm creativity (e.g. [11]). Mostly in popular science or in colloquial use a high number of phenomena of collective intelligence are also termed swarm intelligence or swarm creativity. Although these phenomena seem to be based on natural swarm behavior, they are often not. In biology a swarm is in general a decentralized and self-organized group of similar individuals like ants, bees or termites [4]. Some characteristics exist that are both responsible and necessary for the existence of a swarm (cf. [4] [8]):

- A swarm is composed of many individuals.
- The individuals within a swarm are relatively homogenous (all belong to the same species).
- Swarm behavior and self-organization results from communication of the individuals.
- Interaction and communication among the individuals are rule-based and very simple. Communication happens either in a direct way or an indirect way via the environment.
- The individual has meager intelligence and no supervision.

Bonabeau and Meyer [5] define three reasons for the success of swarms, which have been deduced from the success of social insects, i.e. their diffusion in the ecosphere:

- Flexibility: Normally, it is possible for a swarm to easily adapt to a changing environment.
- Robustness: The existence of the swarm is independent from the single individual. When one or more individuals fail, the swarm can still exist and perform its task.
- Self-organization: There is no central leadership and no local master plan as a guarantee for success.

Because there is no central leadership, only one or a few individuals can initiate a swarm [25]. If an ant finds a food source, it deposits pheromones on the way back to the nest. This is the starting point of a recruitment mechanism, because other foragers follow such trails and swarm behavior emerges, initiated by one ant. The mechanism of self-organization and the whole emergence of a swarm bases on positive and negative feedback, random behavior and multiple communication as well as interaction [4] [25]. An often cited example of swarm behavior is the trail-laying trail-following behavior of ants. If the foraging ant is successful, the exploitation of the food source starts by carrying a piece of food back to the nest. On the way back the ant lays down pheromones to signalize the food source to other ants. Other foragers follow such pheromone trails and the trail is getting stronger. More and more ants will use the trail with the highest pheromone concentration until the food source is exploited. Over time the pheromone concentration is getting weaker. Therefore exploited or less lucrative food sources lose attraction. The final result depends on the positive feedback of this behavior and is the shortest possible distance between the food source and the ants nest. Negative feedback happens here for example by limitations. Newly arriving ants will go on foraging when there are too many ants around the food source. Also important facts are random walks. Not all ants start to follow the strongest pheromone trail. Some ants leave the strongest trail without an observable reason or ignore the pheromone trail from the beginning. The interaction and communication among the individuals in a swarm can be direct or indirect (stigmergy). For example, bees signalize directly new food sources to other bees around, by dancing a so called bee dance. The opposite is the construction of wasp nests. Here indirect communication happens when the individual wasp performs an action which is based on an action that was performed earlier by other wasps. One wasp starts constructing cells of the wasp nest. The existing cells trigger the creation of new cells by other wasps.

The behavior of a swarm creates an overall result that is better than the results the individuals could achieve. Gloor [11] describes this occurrence as
follows: "Individually, one insect may not be capable of much; collectively, social insects are capable of achieving great things. " In other words: What an individual cannot achieve can well be achieved by many individuals organized as a swarm. Based on swarm behavior, optimized solutions can be gained. With respect to ants, it is, e.g., the shortest distance between the discovered food source and the nest. Redundancies are accepted and are not deemed a mistake of this kind of organization [25]. The processes in a swarm are normally not efficient at all. Same or alike core competencies within the same group are quite normal; nonetheless, an optimized solution emerges.

3.2. Design of a swarm-based production of goods and services

The coordination of the production of goods and services in a business network, which is based on swarm behavior of social insects, has not been discussed in literature so far. As mentioned before, the self-organization of business networks is still explored and should have been implemented in virtual organizations by now, but in fact, it is a problem which still exists (c.f. [10]). A possible solution for the implementation of self-organization in business networks could be the transfer of the principles of natural swarm behavior to business networks. The presented reference model aims at optimizing the coordination of goods and services. A starting point for this approach could be the combination of the theory of virtual organizations and the role of service integrators for business networks as described before. To implement a swarm-based coordination, the transfer of typical swarm characteristics to business networks and the involved service providers is promising. Therefore the service providers within the business network have to be interpreted as the swarm. Outside of the swarm the service integrator acts as the coordinator of the swarm. It is important that the service integrator has to be in a decentralized and not hierarchic position. The task of the service integrator is to establish an adequate digital environment to foster swarm behavior of the service providers in form of a communication and interaction framework. Based on this environment, the service integrator enables and initiates swarm behavior among the service providers. The communication and interaction from one service provider to another is essential for swarm behavior. Like ants laying down pheromones, they have to communicate and interact to allow self-organization. The service integrator has to offer open and yet standardized communication channels that can be interpreted by any service provider within the artificial swarm. Therefore, still existing channels and media for communication can be used. Moreover, new ways of communication and interaction through the environment or new communication tools can be developed (e.g. use of digital pheromones) and integrated in the communication and interaction framework. While the service integrator has traditionally a central and hierarchic role in a business network, it is absolute important here that the service integrator is not part of the system of producing goods and services. The service integrator only has to offer information about current and intended customer needs to the service providers, associated to the framework, the same way bees inform other bees by dancing the bee dance. The customer interacts directly with the service integrator and has almost no influence on the service providers.

The service providers act like ants in an ant colony. All service providers associated to the framework constitute the colony. When the service integrator offers the information that a bundle of products and services is demanded, those service providers with the right competencies initiate a new swarm, based on the framework offered by the service provider. The information about the customer need is similar to a food source for ants. The service providers with the required competencies work together to build the bundle of products and services like ants build the trail from the food source to the nest. When the food source is exploited, the bundle is completed by the involved service providers. After that the service providers return to the “colony” and forage for new food sources. During that time, they are still connected by the framework of the service integrator. The traditional approach of a virtual organization is normally defined by combining complementary core competencies. In this case, redundant or nearly redundant competencies by the service providers within the framework are allowed, similar to natural swarms. If one service provider fails within the network, a service provider with similar competencies can substitute the missing provider. In the context of the whole digital market including all actors, the service integrator has to coordinate supply and demand, to develop the framework for swarm behavior and to be an information provider to optimize the production of goods and services, i.e. to fulfill customer needs best. Thus, a new business model emerges for the service integrator. The main tasks are to provide the communication and interaction framework (technical and organizational) to the service providers and to offer information about customer needs and innovative ideas to the service providers which are associated to the framework. Furthermore the service integrator has
to initiate, analyze and interpret the artificial swarm on the customer side to gain ample information about ideas, innovations and customer needs (c.f. [2]). The service integrator so combines the role of a technical service provider and an infomediary. To allow the swarm-based coordination of the business network, it is important, that the service integrator understands the mechanisms of natural swarms. Only this puts the service integrator into the position to offer a framework for service providers that can initiate swarm behavior. Moreover, to be able to analyze the swarm behavior on the customer side, a deep understanding of the mechanisms of swarm behavior is necessary to create useful information for the business network.

Revenues could be generated by this business model by providing the framework, coordinating the business network, providing detailed information about customer needs and innovative ideas through analyzing collective behavior and by providing the bundles to the customers.

The role of the service integrator can be fulfilled by several parties. In an existing business network it could be one of the service providers, who were chosen by other companies of the network or a trusted third party. It could also be an external company who has specialized to be a service integrator. There are already companies which have the potential to become a service integrator of a swarm-based business network. One example is Threadless. On the customer side Threadless already uses collective intelligence. Their core competency is offering the internet platform for the customers. Based on this platform, collective behavior can emerge on the customer side. The production of t-shirts is outsourced to service providers coordinated by Threadless. Here, Threadless could try to use the existing platform to coordinate the production process of the service providers too.

The service integrator has to face specific challenges. The initiation of the swarms has to be done in adequate time to be competitive to other companies and networks outside of the respective swarm. Moreover, legal problems have to be considered. Examples are patents or trademarks for new goods and services produced by the swarm-based network.

The reason behind transferring the approach of natural self-organization of swarms to the production of goods and services in business networks is to gain optimization effects similar to swarms in nature. In an ant colony we can find these effects for example in an optimized path between a food source and the nest. In a swarm-based business network the optimization effect has to be an optimization of the collaboration for the production of goods and services. The following figure shows a cause-effect-model as one possible approach to prove the described swarm-based business network.

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**Figure 1. Swarm-based coordination in a digital market**

4. A cause-effect-model for testing the effects of swarm behavior

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The success of swarms in nature depends primarily on flexibility, robustness and self-organization. Flexibility and robustness are chosen as direct drivers of the performance of swarm-based business networks. Self-organization is split into the factors “communication and information flow” and “decentralized service integrator”, because these are two important factors for the emergence of self-organization. Indicators for the communication and information flow are “synchronism” and “information contents”. An optimal coordination of the network depends on the availability of all needed information. The communication in a swarm is dependent on the synchronicity of the information used. Only if the information contents is synchronous, an effective and efficient coordination of the business network can be gained. The indicator “information contents” is similar to the communication with pheromones in ant colonies. The communication within an ant colony only works, when all ants can interpret the pheromones in the same way. Additionally, the pheromones, interpreted as data, have to carry the right information (e.g. the quality of the food source) [26]. Only when having this information, the ant can decide to go on foraging or to skim the food source. Transferred to a business network, this means the right quality of data and the right information contents are required for an efficient coordination of the production process of goods and services.

The robustness of swarm-based coordination could be measured with the indicators “substitutability” and “reaction time”. The swarm can still exist and perform its task if one individual fails. If one service provider fails within the network, a service provider with similar competencies has to substitute the missing provider. It fails within the network, a service provider with similar competencies is available. The reaction time to substitute the missing provider is also of importance. The result of the production process depends on how fast an adaption to a changed environment is possible.

The indicator “flexibility” with respect to natural swarms refers to the ability to adapt to a changing environment [5]. A swarm-based business network has the goal to satisfy customer needs best and to adapt to changing customer needs. The business network has to offer a wide range of competencies within the network of service providers. Accordingly, flexibility depends on the amount of supply made possible by the size of the network of service providers and number of service providers.

Self-organization in a swarm bases on decentralization and self-organization, i.e. a missing supervisor. Only if the service integrator is in a decentralized position and builds a loose environment, self-organization can emerge. If the centrality is high and the interrelation of the service integrator with the service providers is close, no self-organization can emerge within the business network. In addition to this, factors have to be considered which serve as mediating variables for the performance of the business network. To show the optimization of the swarm-based collaboration for the production of goods and services within business networks, a closer look at the performance of the business network is necessary. To measure the performance, the indicators “production costs”, “customer benefit”, “exploitation of new potentials” and “quality” were chosen [9]. The parameter “performance” is defined as the productivity of the network, i.e. the relationship between output and input. However, productivity in this case cannot just be calculated based on factor prices, but has to also consider qualitative effects of the collaboration within the network. When the performance of the business network is optimized, for example by lower communication or process costs, finally the whole production costs will decline. The collaboration of service providers normally results in a better result of the production process. This could be, for example, an improved time to delivery or higher customer satisfaction. These positive effects can be summarized as “customer benefit”. Moreover, a result of collaboration between service providers can be new business opportunities for individual service providers or for the network as a whole. This could be, for example, the design of new and innovative products by the artificial customer swarm and new opportunities for service providers through learning from the customers. The fourth indicator is quality. A business network offering bundles of products and services to fulfill customer needs best, has to be measured by the quality of the created bundle. The correlation between the collaboration for the production of goods and services and the quality of the final result is also very important.

The correlation between the performance of the business network and the quality of the final result is also very important. A business network offering bundles of products and services to fulfill customer needs best, has to be measured by the quality of the created bundle. The correlation between the collaboration for the production of goods and services and the quality of the final result is also very important.

Figure 2. Cause-effect-model for swarm behavior in business networks
variables that could influence the interaction between the main factors and performance. That could, for example, be the different (corporate) cultures combined in a network, capabilities of the service integrator or the available technology of the single company. As control variables the market performance and the organizational performance are chosen (e.g. measured by value creation). If the performance of the market or a single organization of the business network is increased, it could be relevant for a better performance of the whole network.

5. Conclusion

In this paper we described a basic approach for the coordination of the production processes of adequate and innovative goods and services within a swarm based business network. This approach offers new types of business models for service integrators. It is based on the natural behavior of social insects, the so called swarm behavior. Technological enhancements and changing customer behavior in digital environments are new challenges for creating new business models and the collaborative production of innovative goods and services. Swarm based coordination and collaboration could be one option to meet these challenges. However, it is important to analyze the performance aspects of such an approach; only if companies gain while being part of the “swarm”, the mechanism is going to work. The presented cause-effect-model is a first suggestion for such an analysis. The model is still in its initial stage. Future research has to reevaluate and expand the model to include further influencing factors.

Based on an already existing prototype for the customer side [2], a second prototype is planned to analyze swarm mechanisms on the provider side. As a result of this phase in the research process, a holistic model of a swarm-based value web and the included business network is planned.

6. References


