Taxonomy of collaborative networks forms: FInES Task Force on Collaborative Networks and SOCOLNET - Society of Collaborative Networks

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Taxonomy of Collaborative Networks Forms

FInES Task Force on Collaborative Networks and
SOCOLNET - Society of Collaborative Networks

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Abstract. This chapter is intended as a contribution to the consolidation of base terminology in collaborative networks and thus facilitate the dialogue and collaboration among the Factories of the Future projects included in the FInES cluster. The main current forms of collaborative networks, both in industry and services, are identified and a taxonomy is proposed. For most classes of collaborative networks examples are provided. Emerging application domains are also briefly discussed.

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1 Introduction

There is a growing trend in industry and services to seek synergies through participation in networks. Going beyond the basic idea of a networked-society, dynamic combination of competencies and capacities, resources sharing responsibilities, risks and benefits, in order to fulfill the needs of each business opportunity, give enterprises a high level of agility, competing size, and new survival power in face of market turbulence.

Tools as inductors of new forms. In both industry and services collaborative networks have existed for a long time [1]. For instance, global supply chains can be even exemplified with the ancient Silk Road (Fig. 1-1), where merchants collaborated to gain more profit. During the 15th century, with the navigation ventures, such as those started by the Portuguese, and followed up initiatives by the Spanish and Dutch, the trading networks were reshaped. Centuries later, the global supply chains, mostly focused on basic needs, e.g. agricultural goods and raw materials, were affected and reformed by the Industrial Revolution [2]. More recently, during the 1970s and 1980s, the Japanese manufacturing concepts and techniques, including just-in-time, co-makership and keiretsu networks, attracted the academic/research interest to the analysis of the interactions among autonomous but cooperating entities. In the 1990s, because of the drive for lower costs, greater efficiency and responsiveness to customer demand, the paradigm of core competencies emerged as well as the consequent move to outsourcing. One of the foundational works in this area was the study of the Transaction Cost Economics by Williamson in the 1970s. Particularly along the last decades, the shift from make-or-buy to co-makership and alliances, the search for flexibility, the emergence of concepts for computer integrated manufacturing, fractal company, holonic manufacturing systems, intelligent manufacturing systems, and balanced automation, all demonstrate a continuous move to less monolithic but increasingly inter-connected industrial entities. The industrial networks and concepts of distributed manufacturing are now perceived as potential solutions to the needed flexibility and agility in response to fast changes in market demands. Similarly in many other industrial areas, including the service industry, the emphasis on networking and partnership / cooperation has raised a large interest in a number of new disciplines such as the coordination theory, organizational theory, systems' interoperation, and sociology of the industrial organizations, among others.

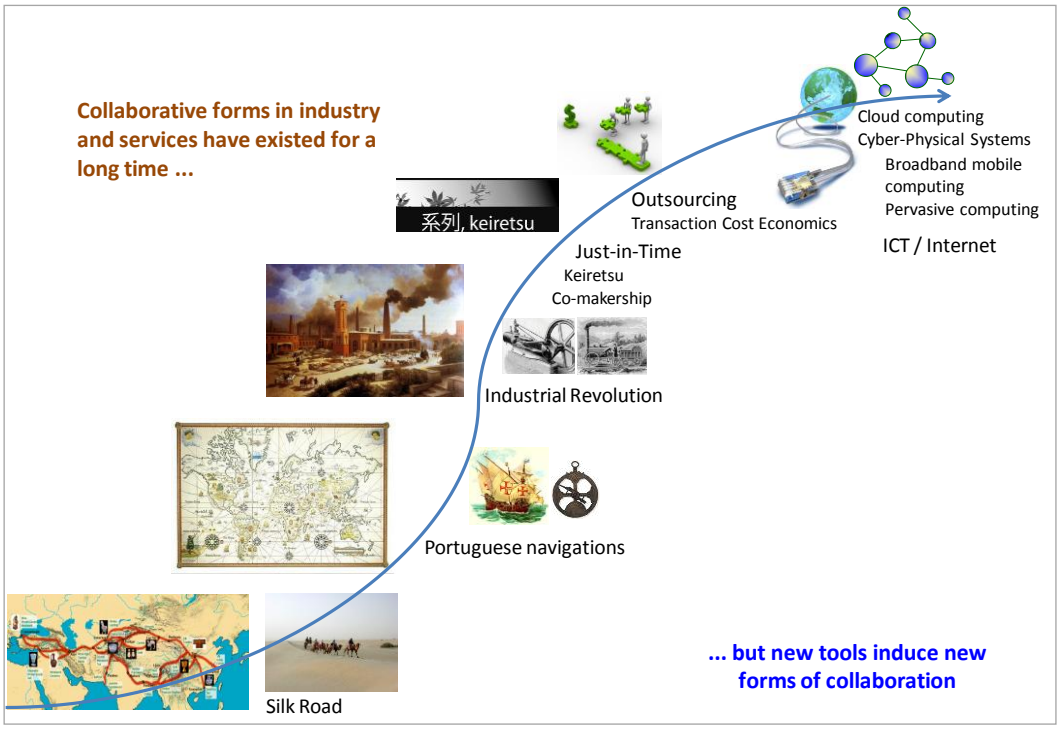

Figure 1-1. Some milestones in collaboration forms

Advances in the ICT area and particularly in the Internet and pervasive computing, have revolutionized virtual collaborations and have enabled and induced the emergence of new organizational forms. Broadband mobile computing, cyber-physical systems, and cloud computing are examples of tools that are pushing the early concepts of collaborative networks to new territories.

Collaborative networks appear nowadays in large diversity of forms and show such a variety of behavioral patterns that lead to some difficulties both in terms of characterization of the paradigm and communication among experts.

Network and community metaphors. The terms enterprise network and collaborative network are inspired by the networking metaphor in the sense that they represent distributed collections of nodes (e.g. enterprises) interconnected by a number of links representing interactions or collaboration relationships between nodes. The fact that the operation of these entities and their inter-relationships is supported by computer networks also re-enforces the use of this term.

In terms of structure, three collaborative network topologies seem to appear frequently in literature [3] (Fig. 1-2): a) chain topology, as in the case of supply chains in manufacturing industries, b) star topology (dominant member), which is typically the case in construction or automotive industries, and c) general network topology, as in creative and knowledge industries. In a chain topology, the nodes' interaction pattern mainly follows a value-chain. In a star topology, nodes interact with one central hub or strategic center, while entities involved in general network topology have multiple relationships among all nodes without hierarchy.

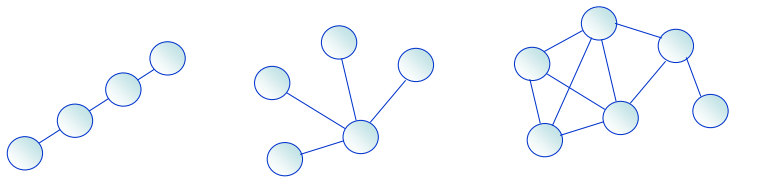

Figure 1-2. Examples of topologies of collaborative networks [3]

However, the network metaphor does not fully capture the highly dynamic reconfigurations of links / relationships, or interactions that go beyond peer-to-peer links, and simultaneously involving several nodes. As we can have a variety of relationships among these nodes, e.g. task coordination, information flow, material flow, task-dependency, etc., an appropriate network-oriented representation would also require inclusion of multiple super-imposed links. Furthermore, the notion of interaction or connection among entities does not fully capture the notion of "togetherness", "joint achievement", or even "membership to a group". In fact, besides peer-to-peer relationships, there are relationships between nodes (members) and the whole group, representing notions such as belonging, recognition, sharing, or loyalty to groups, etc. This other perspective is in fact better captured by the community metaphor. The idea of community is considered implicit in the notions of "group identity", "co-responsibility", "co-creation", and "co-innovation".

From the individual nodes (e.g. enterprises) perspective, this notion represents some degree of diluting one-self in the group (delegating some autonomy) in exchange of privileged access to resources, knowledge, markets, complementary skills, mutual support, risk sharing, etc.

The term collaborative network thus needs to be understood as reflecting ideas inherited from both the networking and community metaphors. Aiming to capture the essence of all these aspects and encompassing a new theoretical framework to support further developments, Collaborative Networks (CNs) has emerged as a new scientific discipline [4].

In terms of duration, we can find short-term networks, typically triggered by a collaboration opportunity, as the case of a virtual enterprise, and long-term networks, as the case of strategic alliances or supply chains. Furthermore, applications in different domains introduce specific terminology for that domain, what increases the difficulties of mutual understanding in an area that is of a multi- and trans-disciplinary nature. In order to cope with such situation, this report is an attempt to clarify the basic concepts and introduces a taxonomy of collaborative networks forms.

2 Base Concepts

In order to properly understand and model collaborative networks it is necessary to first focus on the very notion of collaboration [5], [6]. Although everybody can have an intuitive notion of what collaboration is, this concept is often confused with cooperation. For many people the two terms are indistinguishable. The ambiguities reach a higher level when other related terms are considered such as networking, resource sharing, communication, and coordination [7], [8], [9]. Although each one of these concepts is an important component of collaboration, they are not of equal value neither synonymous.

In an attempt to clarify the various concepts, the following working definitions are adopted [10]:

Definition 2.1: **Networking** – a process involving communication and information exchange among participants for mutual benefit.

It shall be noted that this term is used in multiple contexts and often with different meanings.

The nowadays popular "social networks", such as Facebook, and other forms of simple virtual communities involve mainly networking.

Besides social networks, another simple example of networking is the case in which a group of entities share information about their experience with the use of a specific tool. They can all benefit from the information made available / shared, but there is not necessarily any common goal or structure influencing the form and timing of individual contributions.

In addition to communication and information exchange some structural forms are already present in these networks, as materialized by the notions of "friends" or "followers".

Definition 2.2: **Coordinated Networking** – a process that in addition to communication and exchanging information, involves aligning / altering activities so that more efficient results are achieved.

Coordination, that is, the act of acting together harmoniously, is one of the main components of collaboration.

Some social networks such as LinkedIn, in some aspects are in a transition stage between simple networking and coordinated networking.

An example of coordinated networking activities happens when it is beneficial that a number of heterogeneous entities share some information and adjust the timing of, for example, their lobbying activities for a new subject, in order to maximize their impact. Nevertheless each entity might have a different goal and use its own resources and methods of impact creation.

Definition 2.3: **Cooperation** – a process that involves not only information exchange and adjustments of activities, but also sharing resources for achieving compatible goals. Cooperation is achieved by division of some labor (not extensive) among participants.

Although participants work mostly apart, each one focusing a specific task, these tasks represent a decomposition of a larger process (e.g. to produce a complex product) and from time to time require some synchronization and interaction.

A traditional supply chain based on client-supplier relationships and pre-defined roles in the value chain, is an example of a cooperative process among its constituents. Each participant performs its part of the job, in a quasi-independent manner (although coordinated with others). There exists however, a common plan, which in most cases is not defined jointly but rather designed by a single entity, and that requires some low-level of co-working, at least at the points when one partner's results are delivered to the next partner. And yet their goals are compatible in the sense that their results can be added or composed in a value chain leading to the end-product or service.

Definition 2.4: **Collaboration** – a process in which entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal.

A collaboration process happens for instance in concurrent engineering, when a team of experts jointly develop a new product. From this example it can be noticed that although some coordination is needed, collaboration, due to its joint creation facet, involves seeking divergent insights and spontaneity, and not simply a structured harmony.

This concept is derived from the Latin collaborare meaning "to work together" and can be seen as a process of shared creation; thus a process through which a group of entities enhance the capabilities of each other. It implies sharing risks, resources, responsibilities, and rewards, which if desired by the group can also give to an outside observer the image of a joint identity. Collaboration involves mutual engagement of participants to solve a problem together, which implies mutual trust and thus takes time, effort, and dedication.

In collaboration, parties are more closely aligned in the sense of "working together" to reach the desired outcome, rather than that outcome being achieved through "individualistic" participation constrained by contextual factors such as those imposed by client-supplier or sub-contracting relationships.

The term **e-collaboration** is sometimes used to emphasize collaboration supported by ICT [61].

As implicit in the given definitions and depicted in Fig. 8-40, each of the above concepts constitutes a "building block" for the next definition. In other words, coordination

extends networking; cooperation extends coordination; and collaboration extends cooperation. Thus collaboration is the most demanding concept, requiring a high level of integration among participants.

As we move along the axis from networking to collaboration, we increase the amounts of common goal-oriented risk taking, commitment, and resources that participants must invest into the joint endeavor. In this sense, these various interaction levels can also be seen as a kind of "collaboration maturity level".

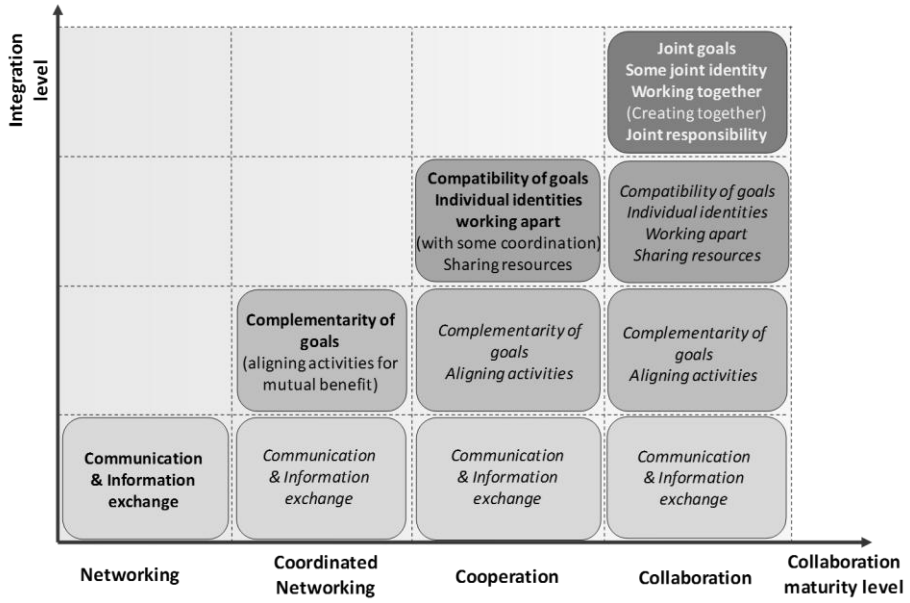

Figure 2-1. Building blocks of collaboration (adapted from [6])

Even with these definitions, in practice the distinction between collaboration and cooperation is not always very clear, as there is often interplay between the two concepts. In fact, in a collaborative network, collaboration in its strict sense does not happen all the time. For example, in the manufacturing alliances, very often there are phases of intense collaboration, e.g. design and planning phases of a project, intermixed with periods when the participants work individually and independently on their assigned tasks. Then from time to time they "come together" (physically or virtually) to integrate their results and continue the joint problem solving. Therefore, a collaboration process clearly involves periods of only cooperation. Understanding and supporting collaboration, which is the most demanding joint endeavor, also leads to understanding and supporting the other less demanding forms of interaction.

Therefore, in the rest of this document we focus on collaborative networks which subsume all other forms.

Pervasiveness of the paradigm. The area of collaborative networks and related concepts already extend over more than two decades of research and development since

the first ideas on virtual enterprises were published. A large number of projects and pilot implementations resulted in a vast amount of concepts, models, mechanisms, systems and tools that are progressively being consolidated to form the scientific foundation for the area.

In terms of application domains, in addition to industry, and as society becomes more interconnected through Internet, a large diversity of collaborative forms are already present in many areas, namely in the services sector. Examples can be found in the elderly care sector, logistics and transportation infrastructures sector, complex systems of systems design, advanced smart electricity grids, and disaster rescue networks, to name a few. Although often adopting a terminology specific to each sector, we can observe that collaborative networks represent now a pervasive paradigm, spanning gradually over all domains.

The notions of collaboration and collaborative networks can be seen from different perspectives, which often lead to different emphasis and even sometimes misunderstandings within the research community. Two dominant views are addressed below:

Enterprise-centric view of collaboration. This perspective tends to analyze the collaboration issues from the enterprise point of view, typically focusing on the management of the relationships with clients and suppliers. The areas of CRM (Client Relationships Management) and XRM (Multiple Relationships Management) reflect this view. Often emphasizing interoperability issues, this perspective suffers from the limitations of an "egocentric view" (namely, the view of "my" enterprise in the center of the world), it is biased by the client-supplier notions, and relatively weak in addressing issues such as co-creation / co-innovation, and global optimization.

In fact this view is more naturally assimilated by the traditional enterprise culture, but not really exploiting the full potential of dynamic collaborative structures. In fact, many developments under this perspective, focus on interactions that are typically limited to one-to-one, and are often governed by sub-contracting models rather than collaboration.

Network-centric view of collaboration. Under this perspective the focus is put on the collaborative network as a whole (namely presenting a holistic view), and thus capturing the notion of a "community". Both the network's endogenous elements (structural, componential, functional, and behavioral dimensions) as well as the exogenous interactions (market, support, societal, constituency dimensions) are considered and addressed.

This view is more adequately representing collaborative networks, when emphasizing: global performance, group governance, structural (organizational) forms, collective / emerging behavior, etc. It is also a more promising representation, regarding the application of collaborative networks to the emerging cyber-physical systems and the complex systems of systems. However, this requires an understanding of the

"collaboration culture" dynamics, which makes it more difficult to be assimilated by traditional enterprises.

Under the enterprise-centric view participants focus on local optima, while facing the "prisoners' dilemma" type of questions - what can I gain, loose, share. Under the network-centric view, which somehow leads to a federated / joint identity, the assumption is that global benefits can better support individual "survival".

3 Base Organizational Forms

3.1 Introduction

Given the large diversity of manifestations of collaborative networks in different application domains, often using different terminologies, it is important to define the taxonomy of the various organizational forms [4], [5], [11] as well as establishing a working definition, though informal, of each element/term used representing each of these forms. Below we provide a set of definitions addressing different kinds of collaborative networks, as also highlighted in Figure 3-1. The numbers indicated for each element in Figure 3-1 also coincide with the order of their definition in this section.

This taxonomy is necessarily open, as new forms of collaborative organizational structures are emerging.

Definition 3.1: **A collaborative network** (CN) is a network consisting of a variety of entities (e.g. organizations, people, or intelligent machines) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by computer network.

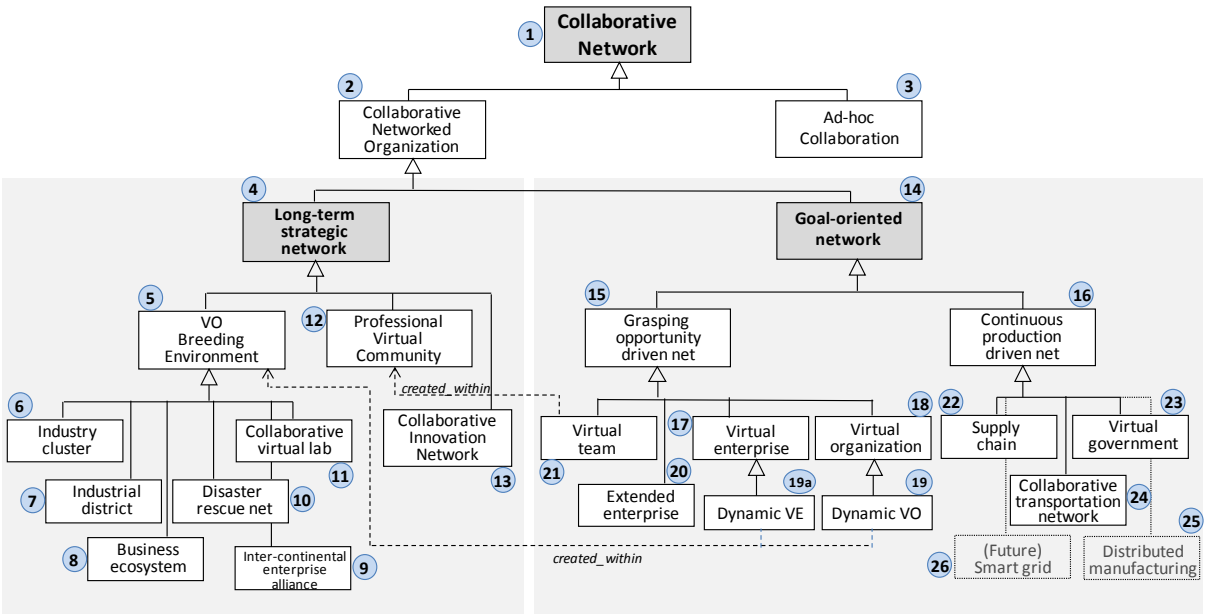

Figure 3-1. Examples of Collaborative Networks

Although not all, most forms of collaborative networks imply some kind of organization over the activities of their constituents, identifying roles for the participants, and some governance rules. Therefore, we can consider:

Definition 3.2: Collaborative networked organization (CNO) – a collaborative network possessing some form of organization in terms of structure of membership, activities, definition of roles of the participants, and following a set of governance principles and rules.

Definition 3.3: Ad-hoc collaboration – a "spontaneous" form of collaboration without a precise structure or pre-defined organization.

Some recent protest movements for example (e.g. "Occupy Wall Street) have some facets of ad-hoc collaboration.

Among the CNOs, we can distinguish between long-term strategic alliances and goal-oriented networks.

*Various **ad-hoc collaboration processes** can take place in virtual communities, namely those that are not business oriented – e.g. individual citizens contributions in case of a natural disaster, or simple gathering of individuals for a social cause. These are cases where people or organizations may volunteer to collaborate hoping to improve a general aim, with no pre-plan and/or structure on participants' roles and how their activities should proceed.*

3.2 Strategic Networks

Definition 3.4: **Long-term strategic network** or breeding environments – a strategic alliance established with the purpose of being prepared for participation in collaboration opportunities, and where in fact not collaboration but cooperation is practiced among their members. In other words, they are alliances aimed at offering the conditions and environment to support rapid and fluid configuration of collaborative networks, when opportunities arise.

When these strategic networks have a business-oriented nature, the term collaborative business community is also used.

Examples of long-term strategic networks include VO breeding environments and professional virtual communities [4], [10], [12], [13].

Definition 3.5: **VO Breeding environment (VBE)** – represents an association of organizations and a number of related supporting institutions, adhering to a base long term cooperation agreement, and adopting common operating principles and infrastructures, with the main goal of increasing their preparedness towards rapid configuration of temporary alliances for collaboration in potential Virtual Organizations. Namely,

A well known example of VBE is Virtuelle Fabrik which is a network of about 70 small and medium enterprises in the metal-mechanics sector, located in Switzerland. A basic ICT infrastructure is used as a communications platform and some level of commonality of business practices and agreed cooperation rules. When a business opportunity if found by any member, acting as a broker, a virtual enterprise is formed with a selected subset of enterprises.

when a business opportunity is identified by one member (acting as a broker), a subset of VBE organizations can be selected to form a VE/VO.

Earlier cases of VBEs were mostly focused on a regional basis, e.g. industry clusters, industry districts, and business ecosystems [13], [14], [15]. Besides the production / services focus, a large number of more recent VBEs address new areas, e.g. science and virtual laboratories, crises management [16]. Some examples include:

Definition 3.6: **Industry cluster** – is one of the earliest forms of VO breeding environments, consisting of a group of companies, typically located in the same geographic region and operating in a common business sector, that keep some "binds" with each other in order to increase their general competitiveness in the larger area. These binds may include sharing some buyer-supplier relationships, common technologies and tools, common buyers, distribution channels or common labor pools, all contributing to some form of cooperation or collaboration when business opportunities arise.

The cluster of mould makers in Portugal is an example. Being located in the same geographical region (Marinha Grande), these companies show some similarity in terms of practices, methods of work, used tools, etc. Often they collaborate in joint projects (workload sharing), but they are not yet organized as a full VBE.

Earlier forms of clusters did not require a strong ICT infrastructure but more and more collaboration resorts to such support.

Definition 3.7: **Industrial district** – is a term mostly used in Italy that represents a concept quite similar to an industry cluster. It can be focused on one single sector or cover a number of sectors in a given region.

The textile district of Lecco, Italy, which brings together companies specialized in the production of furnishing fabrics, especially jacquard and velvets, that aim at keeping high quality standards, propensity for innovation, strong interaction between firms and take advantage of the significant territorial centralization.

Another organizational structure that shares some characteristics with the above examples is the case of incubators. An incubator (of new companies) represents a pool of small companies in their early phase, co-located in the same geographical space, possibly covering different sectors, and that share some basic infrastructures (communications and other generic services) as well as consultancy support in order to evolve towards mature organizations. However, traditional incubators are not yet real VBEs as they usually do not collaborate much in joint business opportunities. Nevertheless it would be reasonable to imagine a next generation of incubators "absorbing" the goals, principles and mechanisms of a VBE.

A similar situation happens with the science and technology parks.

Definition 3.8: **Business ecosystems** – also sometimes called digital ecosystem, is similar to a cluster or industry district, although it is not limited to one sector but rather tends to cover the key sectors within the geographical region. A business ecosystem is inspired by the mechanisms of the biological ecosystems, try to preserve local specificities, tradition, and culture, and frequently benefit from (local) government incentives.

Sometimes the term Digital Business Ecosystem is also used when the intention is to focus more on the ICT support.

In most aspects business ecosystems simply represents a renaming of the industrial district concept. Namely, differences are subtle and can perhaps be found only in a clearer emphasis on the involvement of a diversity of their actors – the living forces of a region – in addition to companies, and a more intense use of advanced ICT tools to support collaboration.

In contexts where the geographical binds are not so relevant, the concept of business ecosystem can be extended, to get closer to the general notion of VBE.

The term services ecosystem, although more strictly technological, shares various characteristics with business ecosystems and VBEs at the abstract level. The basic idea is to have an environment that facilitates rapid composition of (eventually multi-stakeholder) services, forming integrated business services (analogous to consortia formation). This requires that services are prepared to collaborate with each other (an interoperability issue). Similar to a VBE, we can consider in this environment the existence of supporting entities that take care of issues such as quality of service, billing, etc.

In fact, a service ecosystem can be built in the context of a VBE to organize and facilitate the access to services that the VBE members decide to share with / make available to the community.

Definition 3.9: **Inter-continental enterprises alliance** – a special case of VBE involving sub-networks of enterprises in different continents.

The association of the Swiss Microtech network with a Chinese network (DecoChina) is an example of intercontinental VBE.

Definition 3.10: **Disaster rescue networks** – a strategic alliance of governmental / non-governmental organizations specialized in rescue operations in case of disasters is another recent form of VBE aimed at facilitating a rapid and well-coordinated response in case of a disaster. This VBE could have a local / regional coverage or a global geographic span.

Definition 3.11: **Virtual Laboratory (VL) / e-science networks** – represent the alliance of autonomous research organizations, each having their own resources (equipments, tools, data and information related to their past experiments, etc.), enabling their researchers, located in different geographically-spread centers to be recognized and considered for taking part in potential opportunity based problem-solving collaborations (forming a kind of Virtual Organization for each problem solving). During a problem-solving collaboration process, it is typical that some expensive lab equipments owned by one or more organizations is made available for (remote) use by the other collaboration partners.

The VL-e project is an example of a large Dutch initiative to develop support models and tools and establish virtual labs for e-science.

VBE is thus the more recent term that was coined to cover these cases and clearly extends their scope to both regional / global coverage, single / multi-specialty sector, and for-profit / non-profit organizations.

A graphical illustration of the coverage of these organizational forms is shown in Fig. 3-2 (improved from [10]).

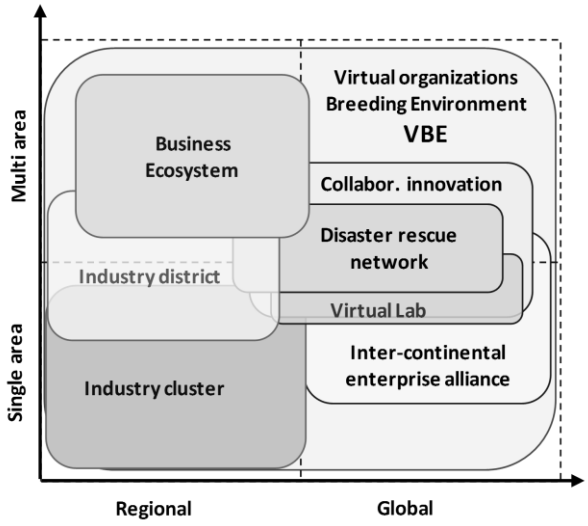

Figure 3-2. Examples of long-term strategic alliances

A similar long-term organization is the Professional virtual community, as defined below.

Definition 3.12: **Professional virtual community (PVC)** - an alliance of professional individuals, which provides an environment to facilitate the agile and fluid formation of Virtual Teams (VTs), similar to what VBE aims to provide for the virtual organizations. It may also include a number of associated supporting institutions.

Examples are Associations of free-lancer knowledge workers (e.g. engineers, consultants).

One such case is the PROJEKTWERK, founded in 1999, that includes about 4500 freelancers and small enterprises. This organization offers functionalities to: Publish profiles, Submit bid invitations, Search for cooperation, and Partners search.

When a business opportunity happens (e.g. a design project or consultation activity), a temporary coalition of experts – a Virtual Team (VT) – can be rapidly formed according to the specific needs of that business opportunity.

In addition to socialization and information/knowledge exchange, which are typical in social networks, a PVC includes also a business component.

Sometimes a PVC may appear in a hybrid form. One case is a collaborative network mainly formed by individual professionals but that might also include, as members, small companies. One example is a PVC of free-lancer software developers that integrates also very small software houses.

Another case is a PVC created inside a VBE, which is aimed at boosting the collaboration among professionals belonging to the various organizations of the VBE.

Definition 3.13: **Collaborative innovation networks (CoIN)** - is a collaborative organization, similar to a PVC, comprising a group of self-motivated people with a collective vision, enabled by Internet and ICT tools, to collaborate in creating a new trend (innovation) by sharing ideas, information, knowledge and work [17], [18].

One example is SpineConnect a worldwide community of spine surgeons interacting in a variety of ways, ultimately with the goal of producing innovation. They share knowledge, develop novel approaches to treatment, address the open challenges in spine healthcare, and create technological solutions with the goal of improving patient outcomes.

The main focus is pursuing innovation, based on the enactment of some form of collective intelligence.

3.3 Goal-oriented networks

Definition 3.14: **Goal-oriented network** – a CN in which intense and well focused cooperation and/or collaboration (towards a common goal or a set of compatible goals) is practiced among their partners.

Goal-oriented networks can themselves be sub-divided into:

Definition 3.15: **Opportunity driven network** – a CN driven by the aim of grasping a single (collaboration) opportunity and that dissolves after the goal is accomplished.

Definition 3.16: **Continuous production network** – a CN driven by or oriented to continuous production / service provision activities.

Examples of opportunity driven collaborative networks include [5], [10]:

Definition 3.17: **Virtual enterprise (VE)** – represents a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose collaboration is supported by computer networks.

A temporary consortium of independent companies involved in a major construction (e.g. new bridge) and that use a computer network and ICT tools to support their collaboration and dissolve after the delivery of the construction product constitute an example of virtual enterprise.

It shall be noted that the term "virtual enterprise" has been often used in the literature with slightly different meanings. For instance, some authors also include in the definition the long-term strategic alliances.

Definition 3.18: **Virtual Organization (VO)** – represents a concept similar to a virtual enterprise, comprising a set of (legally) independent organizations that share resources and skills to achieve its mission / goal, but that is not limited to an alliance of profit oriented enterprises.

A virtual enterprise is therefore, a particular case of virtual organization.

Definition 3.19: **Dynamic Virtual Organization** – typically refers to a VO that is established in a short time to respond to a competitive market opportunity, and has a short life cycle, dissolving when the short-term purpose of the VO is accomplished.

We could similarly refer to dynamic virtual enterprise.

Definition 3.20: **Extended Enterprise (EE)** – represents a concept typically applied to a networked organization in which a dominant enterprise "extends" its boundaries to all or some of its suppliers.

A typical example of extended enterprise can be found in the automotive industry. The car maker, which is mainly responsible for the final assembly, has a dominant role over its network of suppliers. This dominance is reflected in the imposition of tough contractual conditions, namely in terms of quality, delivery times, etc, but also in terms of tools and methods to be used.

An extended enterprise can be seen as a particular case of a virtual enterprise (in case of a temporary and goal-oriented extended enterprise) or of a supply chain (in the case of a long-term structure).

Definition 3.21: **Virtual team (VT)** – a structure similar to a VE but formed by humans, not organizations, comprising a temporary group of professionals / knowledge workers that work together towards a common goal such as realizing a consultancy job, a joint project, etc., and that use computer networks as their main interaction environment.

A group of free-lancing engineers based in different geographical locations can be organized as a virtual team in order to jointly perform a consultancy project.

A virtual R&D team is an example of virtual team that concentrates on R&D tasks and projects [62].

The diagram in Fig. 3-3 illustrates the relationships among various examples of opportunity-driven collaborative networks.

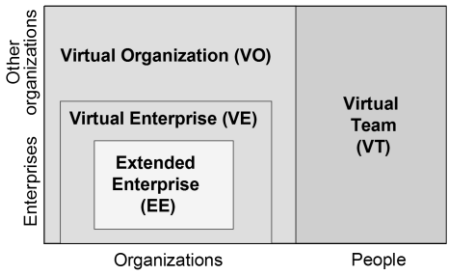

Figure 3-3. Examples of opportunity-driven CNs

The term "virtual" in the above organizations comes from the fact that these networks act or appear to act as a single entity, thanks to their organized communication and coordination mechanisms enabled by computer networks, although they are (usually) not a single legal entity, they may not have a physical headquarter, and are typically geographically distributed.

The case of Continuous production networks includes those networks that have a long-term duration and remain relatively stable during that duration, with a clear definition of members' roles along the value chain. Typical examples include:

Definition 3.22: **Supply chain** – a (relatively) stable long-term network of enterprises each having clear roles in the manufacturing value chain, covering all steps from initial product design and the procurement of raw materials, through production, shipping, distribution, and

A supply chain is the most classical example of networks of enterprises that work in a cooperative way. Examples can be found in all industrial sectors. Classical supply chains are long-term, coordinated, and quasi-static structures.

warehousing until a finished product is delivered to a customer.

Definition 3.23: **Virtual government** – an alliance of governmental organizations (e.g. city hall, tax office, cadastre office, and civil infrastructures office) that combine their services through the use of computer networks to provide integrated services to the citizen through a common front-end.

A real collaborative network in e-government should "hide" from the "customer" (i.e. the citizen) the actual organizational structure of the various governmental entities and provide a unique "front-end" to the citizen.

It shall be noted that most of the so-called e-government initiatives do not correspond to this concept as they basically provide access to government services through the web but do not integrate services involving various governmental organizations.

Definition 3.24: **Collaborative transportation networks** – a long-term CN involving a diversity of actors such as road management entities, logistic operators, parking management entities, gas stations, banks, etc. in order to provide integrated transportation services.

The "Via Verde" organization in Portugal is an example of such innovative network [19].

The next challenge is the development of a collaborative eco-driving environment, focused on effective support of integrated services, targeting transportation energy efficiency, costs saving, and improvement of safety in mobility across Europe. Achieving such infrastructure on a large scale needs the currently fragmented scenarios of multiple stakeholders acting independently (and even in competition) to disappear and be replaced with a collaborative context, promoting integrated services and service innovation.

Simultaneously at the shop-floor level a convergent phenomenon is observed. More and more manufacturing systems are composed of autonomous (progressively more intelligent) components / resources, interconnected by computer networks (a truly ubiquitous computing and sensing environment) forming "coalitions" that need to be easily re-configured as driven by the needs of flexibility and agility. The traditional paradigm of control systems is giving pace to other mechanisms (e.g. coordination, negotiation, fuzzy reasoning, contracting) that are characteristic of collaborative networks, as seen in the most innovative recent proposals for advanced evolvable manufacturing systems architectures [20], [21].

The COBASA architecture applies the collaborative networks paradigm to re-configurability of manufacturing shop-floors [22].

Several other forms of collaborative networks are emerging as a result of both the progress on the information and communication technologies and the progress on the understanding and definition of collaboration mechanisms and supporting frameworks.

For instance, the term distributed or disperse manufacturing network is being used to represent networks of manufacturing entities that can be seen as partly supply chain or VE and partly VBE, depending on the particular instantiation.

Definition 3.25: **Distributed manufacturing systems** - Collaboration in the overall manufacturing process among specialized functionalities at various geographically distributed sites, supported by computer and communication systems.

In fact, the term distributed manufacturing system represents an evolving concept. While originally focused on control of autonomous production cells, it is nowadays extended to cover networked organizations, and includes all issues surrounding industrial [manufacturing] networks [2], [23].

Fig. 3-4 highlights both the commonalities and differences between distributed manufacturing systems and virtual enterprises.

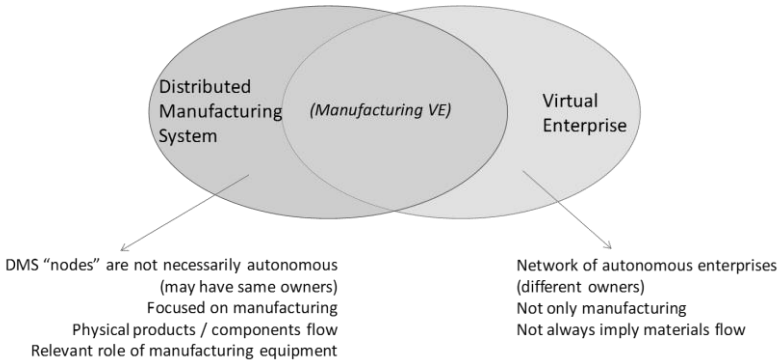

Figure 3-4. Relationship between Distributed Manufacturing System and Virtual Enterprise

Another special application case is emerging in the energy sector:

Definition 3.26: **Collaborative smart grid** – a collaborative network involving diverse stakeholders in the electrical energy sector, as well as the consumers, aiming to improve efficiency and sustainability of electricity related services.

The smart grid represents the move from a centralized, energy producer-controlled network to the one which is less centralized and more consumer-interactive.

The initial concept corresponded to an overlay of the energy distribution grid with advanced information and metering systems. At the current stage, most efforts are still very focused on infrastructure aspects [24], [25]. However, establishing a truly smart grid requires the participation (collaboration) of a large number of stakeholders, including producers, transmission and distribution operators, regulators, policymakers, and consumers. Thus, the next challenge is to adopt organizational models and

governance structures, and to develop advanced tools needed to support collaboration among these players.

3.4 Handling Diversity in collaboration forms

Although the sections above constitute an attempt to classify the main forms of collaborative networks, it is not always easy to classify new application cases.

As mentioned, there are often strong inter-relationships among different classes. For instance, dynamic goal-oriented networks often are created in the context of long-term strategic networks that act as breeding environments for those dynamic (opportunity-driven) structures (Fig. 3-5).

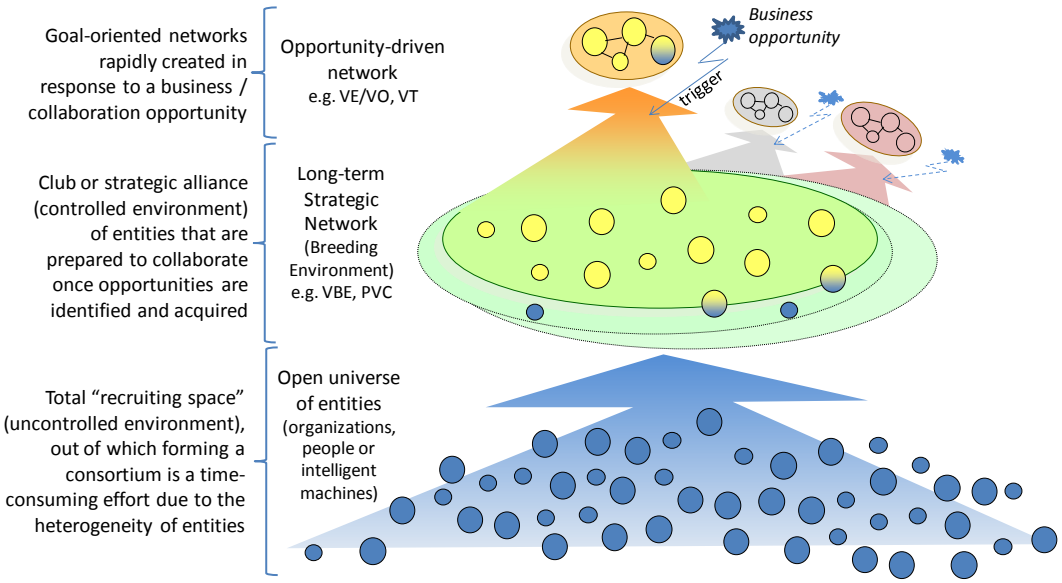

Figure 3-5. Relationship between strategic and goal-oriented networks

As illustrated in Fig. 3-5, the strategic alliances might include diverse degrees of membership, e.g. implementing notions such as core members, associated members, etc.

On the other hand, more and more hybrid forms are emerging. For instance, in the context of the GloNet project [27], which aims at designing, developing, and deploying an agile virtual enterprise environment for networks of SMEs involved in highly customized and service enhanced products, through co-creation and end-to-end collaboration with customers and local suppliers, a mix of long-term and goal-oriented collaborative networks are involved, including:

- Solar plants manufacturers' network: Small and relatively stable VBE, mostly located in Europe, involving members with little overlap, and considering various membership levels.

- Customer's "network": Not clearly organized as a network, but involving some relationships with local suppliers, R&D institutions, regulators, etc., that can play a relevant role in co-creation / co-innovation.
- Product development network: a temporary virtual enterprise whose members come both from the "manufacturers network" and the "customer's network".
- Product servicing network: a long-term virtual enterprise devoted to provide services along the life cycle of the power plants, and whose members come also from the "manufacturers network" and the "customer's network".

This example illustrates a materialization of the Glocal enterprise concept, which focuses on the enterprises that need to understand and think at a global level, while being aware of the local conditions and specificities under which they operate, acting in harmony with the geo-social surroundings [28].

It is also frequently the case that within the context of a formal network, i.e. an organizational structure regulated by a collaboration contract or agreement, a number of informal networks may emerge. These informal networks, typically composed of human members, might have a positive effect in the collaboration processes and even be promoted by the hosting organizations. That is the case of PVCs or CoINs created in the context of a VBE or long-term VE/VO. But other informal networks might have a more hidden or an "underground" nature and resulted from the hidden agendas of some members, reflecting some un-healthy collaboration status.

4 Emerging trends

4.1 Application to new domains

The concept of collaborative networks is emerging as a promising approach in a number of domains. Examples include:

- **Sensor networks**. Considerable progress has been observed in sensor technology and particularly wireless sensor networks. As basic technological issues such as miniaturization, energetic autonomy, and communication capabilities have improved, a growing number of applications are being enabled and developed [29]. The next high-level challenges are focused on how to organize and coordinate "communities" of (intelligent) sensors, how to explore collaborative self-organizing sensor networks in dynamic and fault tolerant environments, how to deal with privacy and safe communications, etc., which can benefit from the models and mechanisms developed in the area of collaborative networks. In fact the term collaborative sensors network is already established [30], [31], [32]. Naturally this area requires addressing issues such as information integration / fusion, quality of information, associated location, big data and data mining, etc.
- **Cyber Physical Systems**. Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the synergy of computational and physical components [33]. Examples can be found in smart electric grid, smart transportation, smart buildings, smart medical technologies, next-generation air traffic management, and advanced manufacturing.
  Recent efforts were focused on connecting objects (devices, sensors, sub-systems) to Internet, which led to the term Internet of Things. After this infrastructure-oriented phase, and when systems tend to involve a large number of entities (hundreds? thousands? millions?), the challenge is how to organize "communities" or "societies" ("ecosystems") of cyber-physical artifacts where flat organizational structures are not appropriate. As the level of intelligence and autonomy of CPS increases, important support can be found in a collaborative networks approach, leading to Collaborative CPS. Complementarily, issues such as real-time discrete event systems, location awareness and location dependency, security, and error recovery are being revisited.
- **Collective Adaptive Systems (CAS)**. CAS is a term used in the FET community [34], [35], representing collective of heterogeneous components that are tightly entangled with humans and social structures. These components increasingly need to evolve, collaborate and function as a part of an artificial society. Decision-making in CAS is distributed and possibly highly dispersed, and interaction between the units may lead to the emergence of unexpected phenomena. CAS can be seen as a collaborative CPS in which the emphasis is put on collective intelligence, problem solving, and adaptive behavior.
- **Smart Spaces, Intelligent Environment**. These terms refer to spaces in which computation is seamlessly used to enhance human activity. Computing power and

sensor systems become invisible as they get embedded into physical objects, (technical) infrastructures, and the surroundings in which we live, travel, and work. In the early developments, research has been much more focused on interoperability for device service mashups [36], [37]. As we progress towards higher abstract levels, these environments also become particular cases of collaborative CPS.

When the ideas are extended to a city, the term Smart City is used, although in this case a network of organizations needs to be also considered (city governance organizations, city mobility services providers, etc.).

- **Systems of systems**. This is an old term from the 1970s [38], [39] that has lately become more relevant as the result of the combination of systems integration, embedded systems, and control systems. These systems try to develop a conceptual framework to address complex systems that are composed of other distributed, loosely coupled and autonomous (operationally independent) components which are large scale systems in their own right. As the research focus turns into collaboration among components, evolution and emerging behavior, as well as management of distributed, independent and heterogeneous elements, a growing match with the collaborative networks discipline can be identified.
- **Open innovation networks**. Open innovation is a concept stating that enterprises, in the process of pursuing innovation, can and should use external ideas as well as internal ideas [40], [41]. The concept of collaborative innovation networks (see section 3) represents a materialization of this idea.

  A particular example is the case of co-creation of new products / services / processes between an enterprise (or a network of enterprises) and its customers and other entities associated to the customers.

  Another case is represented by the notion of crowdsourcing, which involves outsourcing (innovation-related) tasks, traditionally performed by an employee or sub-contractor, to an undefined, large group of people or community (a "crowd"), through an open call. Frequently there is a “prize” for the winning idea (prize competitions). However, traditional crowdsourcing, although resorting to a potentially very large number of contributors, does not typically involve collaboration within the community. Nevertheless, some collaborative-oriented cases might emerge.
- **Collaborative gaming**. Collaborative mechanisms are starting to become prominent in computer games, like massively multiplayer online games [42]. This is certainly a promising area for merging gaming and collaborative networks, but not much has been so far done in this direction.
- **Collaborative logistics**. Logistics deal with the management of the flow of goods/materials between the different points of a distributed system. Logistics processes, which involve multiple operators, namely at global scale, more and more require well established collaborative networks [43], [44]. Collaborative logistics networks (CLN) may also constitute service providers to other collaborative networks (such as a distributed manufacturing network).

- **Elderly care networks**. New integrated and technology-supported services are aimed to face the challenges of rapidly ageing societies. These integrated services tend to be the result of collaboration among multiple stakeholders. Therefore, the concept of collaborative networks is emerging as a promising framework for the development of such services [45]. Notions such as collaborative care communities, collaborative platforms, trusted knowledge network, participatory communities, inter-generational collaboration, etc., are now emerging in the ICT and Ageing area.
- Gr**een virtual enterprise and Green virtual enterprise breeding environment**. Naturally concerned with sustainability issues, these concepts result from the combination of the VE/VBE concepts with the notion of Industrial Symbiosis [46]. The consideration of a collaborative networks approach in the industrial symbiosis, offers their members the opportunity to collaboratively optimize resources utility and at the same time open new possibilities to explore green business opportunities in the global marketplace that would not be possible, or would imply a higher cost, if attempted individually. A more general perspective is related to the role of collaborative networks in sustainability [26].
- **Learning collaborative networks**. Although e-learning is a well established area, new approaches in collaborative learning are emerging and new tools are being developed. For instance, notions of user generated content and collaborative problem solving have similarities with the notion of co-creation [47]. A CN approach is also promising in project-based learning involving students from different areas [48]. A more classical idea is a collaborative network of education institutions and/or educators (virtual institute) to jointly delivering a course.

As mentioned above, these are just some examples of new areas where collaborative networks are being applied and new collaborative organizational structures are likely to emerge.

4.2 Collaborative networks and FInES roadmap

FInES research roadmap [49], which takes an enterprise-centric view of collaboration, instead of a network-centric view, identifies a number of desirable profiles for the future Internet-based enterprises:

- Humanistic enterprise – puts the persons at the centre, focusing on producing wealth and well-being;
- Inventive enterprise – aims to deal with the entire lifecycle of innovation;
- Agile enterprise – enables reacting to endogenous and exogenous (unexpected) contingencies;
- Cognisant enterprise – goes beyond knowledge management, aiming at acquiring and effectively exploiting new knowledge;
- Sensing enterprise – views enterprise as a smart complex entity capable of sensing and reacting to stimuli (internal and external);

- Community-oriented enterprise – addresses leveraging on the social intelligence of different communities, both internal and external;
- Liquid enterprise – refers to the blurring of enterprise borders, through intensification of collaboration with partners, competitors, and customers;
- Glocal enterprise – enables to think and act globally, while being aware and responding adequately to local specificities;
- Sustainable enterprise –addresses meeting the needs of the present without compromising the ability of future generations to meet their own needs.

These profiles can, in fact, be seen as desirable qualities for facilitating the participation of enterprises in a variety of collaborative organizational forms, as illustrated in forms of CNs, VBEs, PVCs, VEs, etc. in Fig. 4-1.

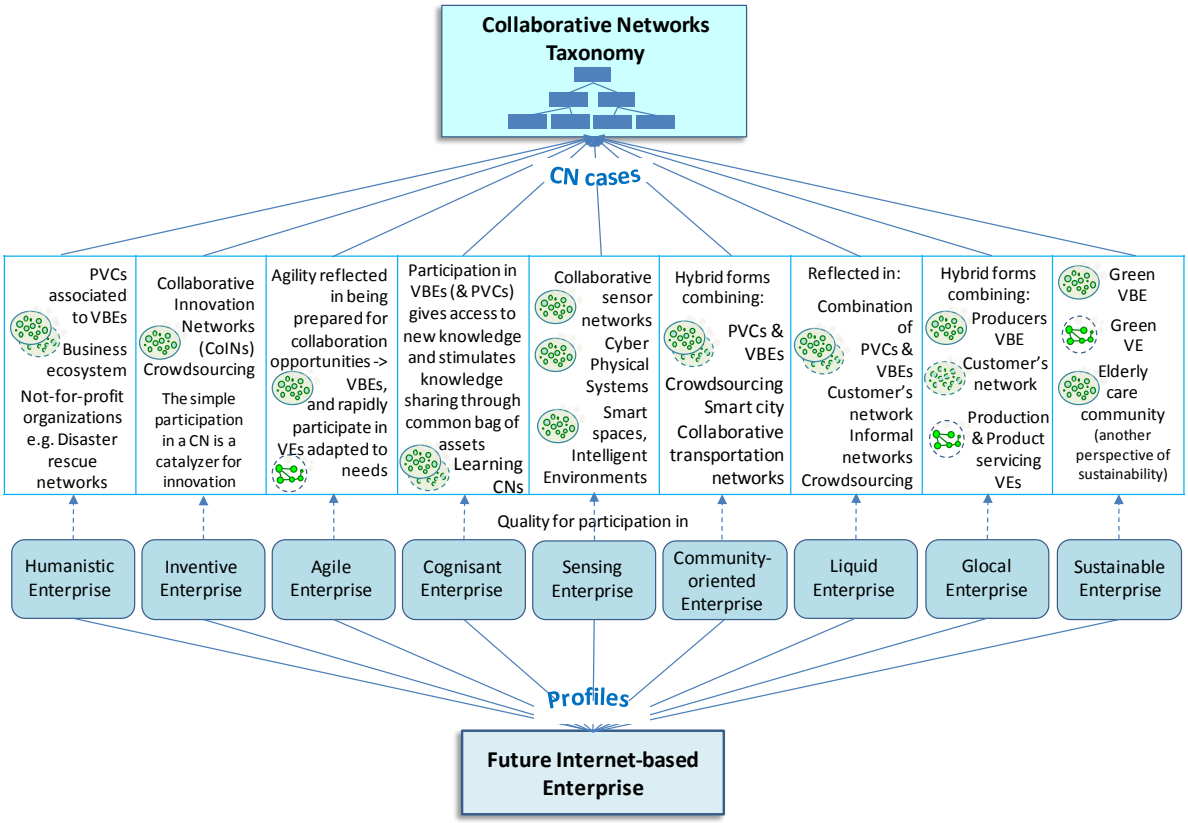

Figure 4-1. Relationship between future Internet-based enterprise profiles and Collaborative Networks

It shall be noted that the exemplified cases are only a small part of the full spectrum of the collaborative network forms discussed in previous sections, which can only be fully captured when taking a network-centric view, a perspective not yet reflected in the current draft of the FInES roadmap.

4.3 Reference modeling framework

Given the diversity of cases and their trans-disciplinary nature, collaborative networks are complex entities whose proper understanding, design, implementation, and management require the integration of different modeling perspectives. It would be particularly useful to have some form of reference model i.e. a generic conceptual model that synthesizes and formalizes the base concepts, principles and recommended practices for collaborative networks. Prior to the establishment of a reference model it is necessary to adopt an adequate modeling framework. As such it is important to have a comprehensive modeling framework that facilitates the understanding of the area.

Although several modeling frameworks exist for the case of single enterprises – e.g. Zachman [50], CIM-OSA [51], PERA, GRAI-GIM [52], and GERAM [53], [54] – not so many results are available for enterprise networks or collaborative networks in general. Some works have focused on a number of partial modeling aspects. For instance, business process modeling for supply chains has been extensively addressed in the SCOR framework [55]. Models focused on planning and control for production networks have been proposed by Kuehnle [23]. Extensions of GERAM for enterprise networks have also been attempted to some extent [56]. The Federal Enterprise Architecture [57] addresses the cooperation among different governmental organizations, providing a comprehensive model, but limited to the considered domain. Another partial contribution, focused on the resources perspective, is the Enterprise Grid Reference Model developed by the Enterprise Grid Alliance [58] which defines the terminology and glossary of grid computing and identifies various components, interfaces, interactions and data models.

A more comprehensive modeling framework proposal for collaborative networks is the ARCON (A Reference Model for Collaborative Networks) Framework [59]. ARCON offers a 3-dimensional approach to model collaborative networks, including: 1) the CN life cycle dimension, 2) the CN environmental perspectives dimension, including the Endogenous Elements, and the Exogenous Interactions, and 3) the CN modeling intent dimension:

Life cycle. The first defined perspective of ARCON addresses the timing cycle of different CN life stages. This perspective captures the evolution of CNs and the diversity during their entire life cycle:

- *Creation* – The creation stage deals with incubation, system parameterization, data and knowledge bases creation, generation and definition of ontology, data/information loading, etc., and can be divided into two phases, namely:
- *Initiation and Recruiting*, dealing with the strategic planning and initial incubation of the CNO, and
- *Foundation*, dealing with the constitution and start up.
- *Operation* – When the CN actually operates towards achieving its goals. Depending on the type of CN, different tasks will be executed at this stage. For example, during this stage, the Virtual organizations Breeding Environments involve in member registration, establishment/maintenance of partners directory of

profiles/competencies, VO establishment and contracting, etc. But the VOs during this stage are mostly focused on co-developing their aimed products/services.

- *Evolution* – During the daily operation stage of a CN, it becomes necessary to make some changes to the CN, e.g. to its membership, structural relationships, roles of its members, etc.
- *Dissolution* – A short-term CN, such as a Virtual Enterprise, will typically dissolve after accomplishing its goals.
- *Metamorphosis* – In the case of a long-term alliance, e.g. a VBE or PVC, considering its valuable bag of assets gradually collected during its operation, its dissolution is very unusual. Instead of dissolution, it is much more probable that such a CN goes through a metamorphosis stage, where its general form and/or purpose can evolve. Such stage may involve the transfer of collected knowledge/information, as well as the members to a third party.

Environment perspective. This perspective focuses on capturing the CN environment characteristics, which further includes two subspaces (points of view) that comprehensively cover, the internal elements characteristics (labeled "Endogenous Elements") of CNs, as well as the external interactions characteristics (labeled "Exogenous Interactions") that address the logical surrounding of the CNs.

For the Endogenous Elements perspective the following sub-dimensions are considered:

- Structural dimension - the structure or composition of the CN in terms of its constituting elements (participants & their relationships) as well as the roles performed by those elements and other characteristics of the network nodes such as the location, time, etc.
- Componential dimension - the individual tangible / intangible elements in the CN's network, e.g. the resource composition such as human elements, software and hardware resources, information and knowledge. Furthermore, this dimension also consists of ontology and the description of the information/knowledge.
- Functional dimension - the "base operations" available at the network and the execution of time-sequenced flows of operations (processes and procedures) related to the "operational phase" of the CN life cycle.
- Behavioral dimension - the principles, policies, and governance rules that drive or constrain the behavior of the CN and its members over time. Included here are elements such as principles of collaboration and rules of conduct, contracts, conflict resolution policies, etc.

Under Endogenous Interactions the following sub-dimensions are included:

- Market dimension - issues related to the interactions with "customers" (or potential beneficiaries) and "competitors". Customers' facet: transactions and established commitments (contracts), marketing and branding, etc. Competitors' side: market positioning, market strategy, policies, etc. can be considered. The purpose / mission of the CN, its value proposition, joint identity, etc. are also part of this dimension.
- Support dimension - issues related to support services provided by third party institutions. Examples: certification, insurance, training, external coaching, etc.

- Societal dimension - issues related to the interactions between the CN and the society in general. The idea is to model the impacts the CN has or potentially can have on the society (e.g. impact on employment, economic sustainability of a given region, potential for attraction of new investments) as well as the constraints and facilitating elements (e.g. legal issues, public body decisions, education level) the society provides to the CN development.
- Constituency dimension - interactions with the universe of potential new members of the CN, i.e. the interactions with those organizations that are not part of the CN but that the CN might be interested in attracting. General issues like sustainability of the network, attraction factors, what builds / provides a sense of community, or specific aspects such as rules of adhesion and specific "marketing" policies for members, are considered here.

Modeling intent. This perspective addresses three possible modeling stages for CN elements, from the general representation, to the specific models (e.g. using a specific modeling approach or theory), and finally to the detailed specification of the implementation architecture for the CN elements:

- General Representation layer – that includes the most general concepts and related relationships, common to all CNs independently of the application domain.
- Specific Modeling layer – an intermediate level that includes more detailed models focused on different classes of CNs.
- Implementation Modeling layer – that represents models of concrete CNs.

Currently only a textual description at the general representation layer exists [60].

5 Conclusions

With the fast developments in collaborative networks, it is becoming very relevant to make an effort to systematize and structure the existing knowledge, first in order to facilitate mutual understanding among the members of this community; second as a contribution to a sound theoretical foundation to boost the developments of collaborative networks and to better support their management and operation. Such effort includes both a clarification of the base concepts and the elaboration of the taxonomy of collaborative forms. A number of European research projects as well as the Society of Collaborative Networks (SOCOLNET) have been contributing towards this aim. The definitions and taxonomy presented in this report are a partial result of these efforts.

Nevertheless, the included propositions should be considered as "working definitions" since new developments and emerging applications in a large diversity of domains will certainly require periodic revisions of the taxonomy.

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